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MASTERARBEIT

A CASE STUDY OF USER BEHAVIOUR AND INDOOR CLIMATE IN AN OFFICE BUILDING IN KOSOVO

ausgeführt zum Zwecke der Erlangung des akademischen Grades
einer Diplom-Ingenieurin

unter der Leitung von
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Abstract

This work presents the results of a study on user behaviour and building systems in Kosovo. The focus was on the OSCE (Organisation for Security and Co-operation in Europe) building in Prishtina.

The main objective of the project is to observe and analyze indoor climate conditions and occupant's behaviour at workspaces, and to find measures to enhance the building's thermal performance and efficiency.
In the study of the thermal performance of the OSCE building, indoor data loggers were used to monitor events and states in seven offices over a period of six months (December 2008 to June 2009). Events and states such as occupancy, temperature, relative humidity, illuminance and status of electrical fixtures were recorded every 15 minutes. The recorded data were processed and analysed.

Based on the results from the research, the interaction between occupants and building systems was found to affect thermal comfort and energy use of buildings. Therefore, it is necessary to have accurate information about user control behaviour in office buildings in order to improve building performance and energy consumption. These behavioural patterns can be used to develop a basis for evaluating the influence of occupancy on building energy consumptions, building simulation programs and intelligent system control strategies.

Keywords: Thermal comfort, user control actions, occupancy, behavioural models, lighting, shading, and efficient systems

Kurzfassung

Diese Arbeit präsentiert die Ergebnisse einer Studie über das Nutzerverhalten und die Gebäudetechnik in Kosova. Der Schwerpunkt lag auf dem Gebäude der OSZE (Organisation für Sicherheit und Zusammenarbeit in Europa) in Prishtina.

Der Schwerpunkt des Projektes ist es, die internen klimatischen Bedingungen und das Verhalten der Mitarbeiter in ihren Arbeitsbereichen zu beobachten und zu analysieren, sowie Maßnahmen zur Verbesserung der thermischen Leistung des Gebäudes zu erarbeiten.

In der Studie zur thermischen Leistung des OSZE-Gebäudes wurden Datenlogger für den Innenbereich verwendet, um Ereignisse und Zustände in sieben Büros über einem Zeitraum von sechs Monaten (Dezember 2008 bis Juni 2009) zu beobachten. Ereignisse und Zustände wie Belegung, Temperatur, relative Luftfeuchte, Beleuchtungsstärke und den Zustand der elektrischen Leuchten wurden alle 15 Minuten aufgezeichnet. Die aufgezeichneten Daten wurden verarbeitet und analysiert.

Die Ergebnisse dieser Forschung zeigen, dass das Zusammenspiel zwischen den Bewohnern und der Gebäudetechnik die thermische Behaglichkeit und den Energieverbrauch von Gebäuden beeinflusst. Man benötigt deshalb genaue Informationen über das Steuerungsverhalten der Benutzer in Bürogebäuden, um die Leistung des Gebäudes und den Energieverbrauch zu optimieren. Diese Verhaltensmuster können als Grundlage verwendet werden, um den Einfluss der Belegung auf den Energieverbrauch des Gebäudes zu bewerten, sowie Bausimulationen und intelligente Steuerungssysteme zu entwickeln.

Schlagwörter: thermische Komfort, Benutzersteuerung, Belegung, Verhaltensmodelle, Beleuchtung, Beschattung, effiziente Systeme

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Dedicated to my father

INTRODUCTION

1.1 Overview

This thesis presents the results of a study on user behaviour and building systems in Kosova. The focus was on the OSCE (Organisation for Security and Co-operation in Europe) building in Prishtina. The study had the main aim of increasing the building's thermal performance and efficiency. With the growing burden of energy provision and its related prices, improving the efficiency of buildings becomes a main priority.

Researchers and the building industry are working on the development of new and efficient materials. Also, simulation software is being improved towards a better prediction of energy performance and indoor climate. It is therefore important to consider the study of building occupants and their behaviour at workspaces. The interaction between occupants and building systems affects thermal comfort and energy use of buildings. Consequently, building occupants should portray energy conscious behaviour.

User behaviour in buildings is mainly an attempt to attain comfort, which depends on physical and psychological factors. Furthermore, issues related to the positioning of spaces, orientation, age, gender, culture, etc. affect comfort. All these factors need to be studied effectively in order to contribute to a better and sustainable environment.

In the study of the thermal performance of the OSCE building, indoor data loggers were used to monitor events and states in seven offices over a period of six months (December 2008 to June 2009). Events and states such as occupancy, temperature, relative humidity, illuminance and status of electrical fixtures were recorded every 15 minutes. The data have been analysed and are hereby presented.

Chapter 1 of the thesis deals with the introduction (motivation and background), chapter 2 describes the methodology (data processing, measuring equipments and collection of data), and chapter 3 presents the results of occupancy, lighting, thermal comfort and interviews. In addition, chapter 4 shows the discussion of the results whereas chapter 5 outlines the conclusion.

1.2 Motivation

With most of the urban population spending many hours in office buildings, it is imperative to provide a good indoor climate and efficient building systems. The use of intelligent occupancy systems, daylight responsive lighting devices and controls have been found to save about 70% of electrical energy used in office buildings (Mahdavi 2007).

Another factor related to the high energy use of office buildings is the provision of thermal comfort. Thermal comfort is defined as the state of the mind which expresses satisfaction with the surrounding environment (ASHRAE 2004). Thermal comfort however requires a subjective evaluation (Szokolay 2004). The factors affecting thermal comfort depend on four environmental and two personal parameters. The environmental parameters are dry bulb temperature, mean radiant temperature, relative humidity and air velocity whereas the personal parameters are clothing-insulation and physical activity.

The evaluation of satisfaction at workspaces makes use of the above parameters to calculate the Predicted Mean Vote (PMV) and the Predicted Percentage of Dissatisfied (PPD).

Studies on user behaviour and interaction with building systems for comfort reasons have increased the knowledge and understanding of building performance.

For instance, Hunt et al. (1998) and Pigg (1998) observed that the switching on or off of lights either happen when building occupants arrive or leave their workspaces. Electrical lights are also known to generally use 20 to 30% of a buildings total energy. Besides, behavioural patterns have resulted in the effective prediction of energy performance of office buildings. These buildings are responsible for a considerable share of the total European energy use and the major part of the use takes place after the production phase (Energy efficient behaviour in office buildings, Ebob).

In this context, the thesis presented deals with the study of user behaviour and installed systems towards the improvement of building performance and thermal comfort of office buildings in Prishtina.

1.3 Background

Research on user behaviour and interaction with building systems has increased the awareness on understanding behavioural patterns and the corresponding energy use of office buildings.

Hunt (1979) was the first to study user behaviour regarding switching actions in office buildings. Hunt found out that all luminaries in one room were usually switched on or off at the same time.

Hunt (1998), Love (1998) and Reinhart (2001) found a close relationship between illuminance on the working area on arrival and switching the lights on by the occupants (Fig. 1)

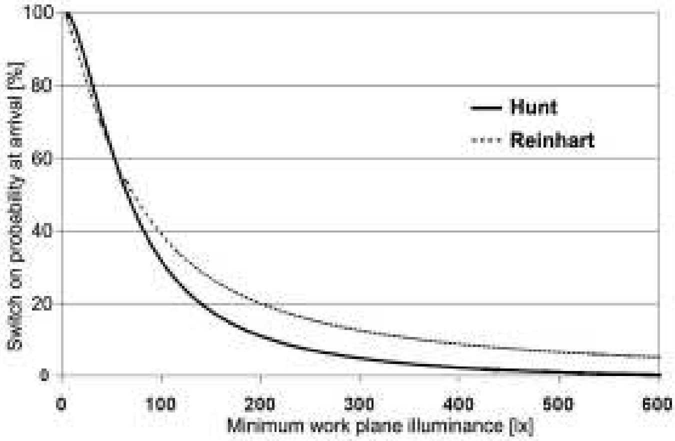


Fig. 1: The probability of switching the lights on upon arrival by office occupants (Hunt and Reinhart)

Love also studied user behaviour and interaction with building systems. Based on observations, Love divided the occupants into two groups:

- Those who turn on the lights and leave them on even when they are not in the office and during intermediate absence.
- Those who turn on the lights only when the illuminance is low.

Reinhart (2002) monitored blinds and manual controls of electric lighting. He tried to find out if manually controlled electrical lighting systems and automatically controlled blinds with manual impact were operated in relation or independent to each other. Reinhardt's study showed that there was an increasing probability of lights being switched on if illuminance was less than 100 lx.

Ebob (Energy efficient behaviour in office buildings) (2006) also recommends the switching off of lights when offices are empty as a sustainable measure to save energy. Further, efficient building performance is mainly related to the design of installed systems and the interaction with these systems by the occupants.

Ebob (2006) concludes that there are four main factors which should be considered in efficient building performance:

- Building technology;
- Installation technology;
- Smart controls of installation;
- Interaction between behavioural aspects and energy saving technology.

The prime aim of Ebob (2004) is to create new technical and socio-economic solutions to make energy efficiency easy for end-users in existing and new office buildings. However, efficiency alone would fall short of sustainable principles if the behaviour of occupants is neglected. Mahdavi et al (2007) found out that in buildings with efficient installed systems, negative behaviour of the occupants contributed to high energy use.

Notwithstanding the complex nature of thermal comfort, researchers are undertaking projects to better understand the production of heat and the associated responses by human beings, conscious feelings about the environment, and the processes of heat transfer between man and his surroundings (Fergus and Nicol 2005). Nicol (2005) also found out that building occupants interact with available building systems in order to create pleasant indoor conditions.

In addition, studies conducted in air-conditioned buildings show that the occupants are not satisfied with the indoor climate during the winter and summer months. Even in buildings with sophisticated thermal controls, dissatisfaction with the indoor climate prevailed. Occupants tend to report on issues relating to overheating and under-cooling during the winter and summer months.

Recently, a survey in Sydney found out that about 80% of occupants in air-conditioned buildings were thermally not satisfied (London Metropolitan

University. Student Notes, February 2005).

Against the background of higher energy use of air-conditioned buildings as compared to naturally ventilated types, studies into user behaviour, installed systems and interaction with thermal control devices are paramount.

RESEARCH DESIGN

2.1 Object description

The main focus of the study is the OSCE (The Organisation for Security and Co-operation in Europe) building in Prishtina, Kosova. The building housed the Bank of Ljublana until the year 2000. Henceforth, the case study building will be referred to as "HQ".

Fig. 2: Geographical view of HQ Building

The HQ building is curtain walled (reflected glazing) with a total of nine floors. The seven observed offices are on the first, second, mezzanine, seventh and eighth floors with different orientations. Fig. 3 shows the general view of the building in Prishtina.

Fig. 3: General view of HQ building (right: the building after the year 2000; left: the building before the year 2000)

2.2 The offices and occupants

Seven offices of different sizes and orientations were monitored during the observation period (December 2008 to June 2009). For instance, the single occupancy offices were of about 16 m^2, triple occupancy of 16 m^2 and other multiple occupancy offices ranged between 30 to about 45 m^2. The mezzanine is an open office landscape with about 10 workers. The monitored office spaces are located on the first, second, seventh, eighth and on the mezzanine floors of the HQ building. Typically, the workspaces are carpeted whereas the corridors are of granite stones. The walls are painted in white and the ceilings are suspended. Fig. 4 shows some interior views of sample offices and Fig. 5 illustrates plans and orientations of the offices.

Fig. 4: Left: View of multiple occupancy office on the second (left image) and eighth (right image) floor.

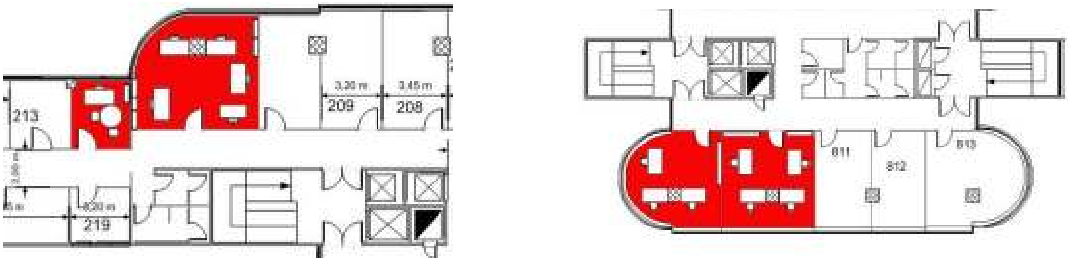


Fig. 5: View of floor plan of multiple occupancy office on the second (left image) and on the eight (right image) floor

2.3 Building systems

The installed lighting systems are fluorescent tubes (18 and 36 watts) with two manually controlled switches located near the entrance. The centrally controlled heaters (radiators) are located under the windows. Due to the inefficiency of the central heating and cooling system, window air-conditioners have been installed in the offices to support the provision of comfort at the workspaces. The central heating, ventilation and air-conditioning (HVAC) systems are operated from 07:00 to 18:30. The cooling system is used from May to September whereas heating is provided from October to April. There are also internal shades which are manually controlled.

2.4 Data collection

From December 2008 to June 2009, data was collected to effectively study the thermal conditions and user behaviour in the offices. This was made possible through the use of sensors to monitor the indoor environment and occupants operational activities. The data was recorded every 15 minutes and downloaded every 30 days.

2.4.1 Internal environment

Indoor climate parameters (temperature, light intensity and relative humidity, presence of the users and state of artificial lighting) were measured using two different types of data loggers (Hobo U12-012 and IT-200). The data loggers were mounted under the light fixtures and around the workspaces.

2.4.1.1 Indoor temperature/ relative humidity/ light intensity

Indoor temperature, relative humidity and light intensity were measured using hobo data loggers (Hobo U12-0 12 sensors manufactured by Onset Inc.). The data loggers were set to record every 15 minutes after which the indoor parameters were downloaded every 30 days using Greenline software. The software was also used to launch the sensors (Fig. 6).

Fig. 6: Image of the Hobo sensor/logger

When mounting the data loggers, direct sunlight was avoided and occupants were instructed not to deposit any items on the sensors. For detailed information on the data loggers, please see Appendix A.

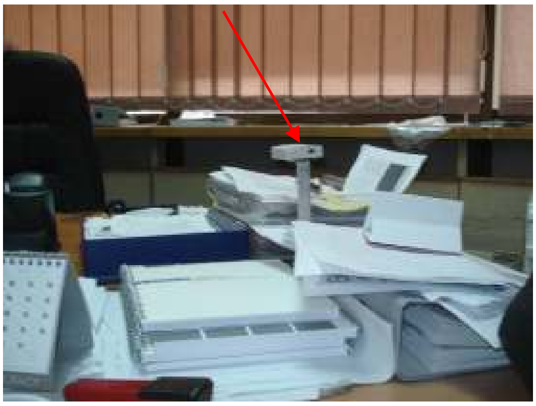


Fig. 7: Image showing a mounted sensor at a workspace on the eighth floor

The sensors were named using a 12 digit code comprising the room number, sensor ID and installation date. For example, "103_201_081224" meant: room number 103, sensor ID 201 and installed on the 24.12.2008. Fig. 8 shows mounted sensors at different workspaces.

Fig. 8: Mounted sensors at workspaces on the second floor

2.4.1.2 Occupancy/ state of light

To monitor the presence of office workers at their stations, IT-200 loggers manufactured by Wattstopper Inc. were used to log occupancy and the state of artificial lighting (on/off), (see Fig. 9).

Fig. 9: Image showing an IT-200, occupancy/state of light (on/off) sensor

The sensor (IT-200) utilizes passive infrared technology to detect and record occupancy and lighting status. Luminance is observed through a plastic pipe to determine if lights are on or off (Wattstoper 2009). The loggers were installed in the immediate proximity of the luminaries and protected against direct sunlight. Also, the loggers were mounted in such a way that a clear view of the workspaces could be observed (Fig. 10). The data recorded was downloaded using a laptop computer every 30 days with ITProSoft (IT-200) software. For detailed information on the IT-200 sensor, see Appendix A.

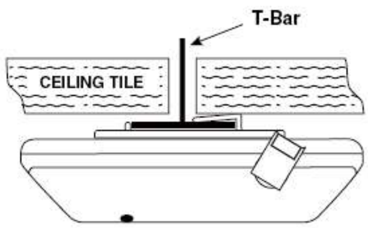


Fig.10: Installation of occupancy and state of light (on/off) sensor

The sensors were named using a 12 digit code which comprised the room number, sensor ID and installation date. The sensor ID for IT-200 loggers starts with "1", for instance "103_101_081224" means: room number 103, sensor ID 101 and installed on the 24.12.2008. The images below illustrate some of the installed sensors on the ceiling.

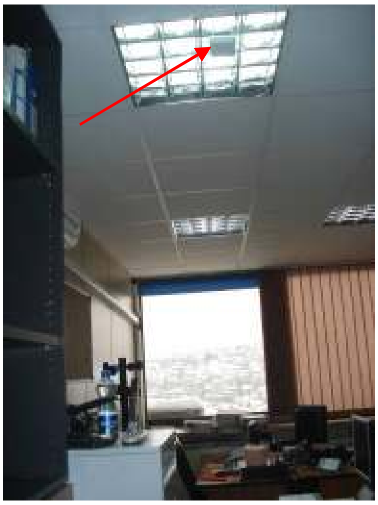
 

Fig. 11: Shows the IT-200 sensor placed on mezzanine (left image) and on the eighth floor (right image)

2.5 Interviews

At the end of the observation period, the building occupants were interviewed on their views and perception towards their indoor climate. In all, 18 people responded to the interviews which were held through a set of questions. The questionnaire was structured in sections, with the first part dealing with personal and general information (gender, age, etc) of the occupants. The second section had questions related to indoor climate (temperature, day/artificial lighting, air-conditioning, heating, etc). The third part examined the operation and accessibility of the occupants to the installed systems and system controls. The fourth section explored the functionality of the building systems and finally, the fifth section looked at issues related to personal preferences and health complaints.

2.6 Data processing

2.6.1 Overview

Over a period of six months (24th December 2009 to 30th June 2009), calibrated data loggers were installed in the offices to record indoor temperature, relative humidity, illuminance, occupancy, and light switching (on/off) states in seven offices. The extensive data collected was structured in MS Excel sheets and analysed. Fig. 12 shows an example of the structured data.

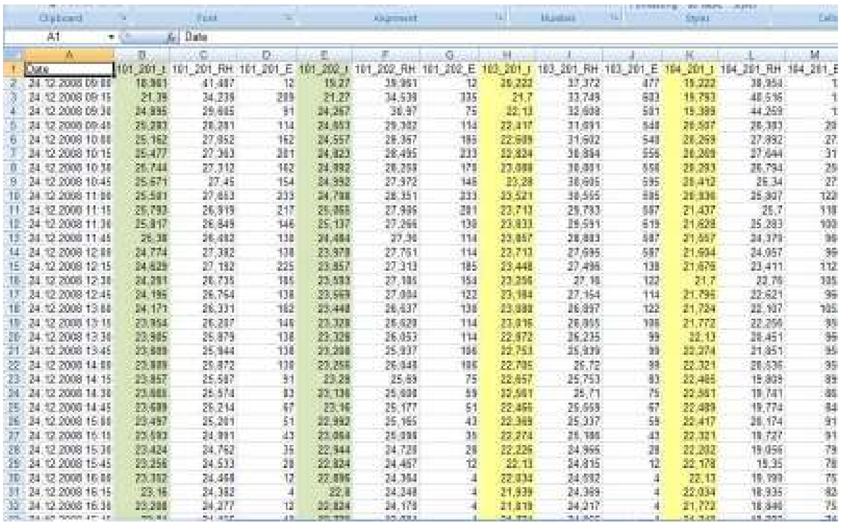


Fig. 12: An example of data processed in Excel sheets (mezzanine and second floor data)

The processed data was further used to analyze thermal comfort conditions in the offices by applying the Fanger method. Thus, temperature, relative humidity values and metabolic rates were computed to calculate the predicted mean vote and the predicted percentage of dissatisfied. Also, psychrometric charts were generated to study the indoor thermal conditions in the building.

2.6.2 SenSelect

To efficiently analyse the data, SenSelect application was used to structure and synchronize the recorded values in 15 minutes time intervals. This application was based on Mathlab and was developed by Pröglhof (a member of the Institute of Building Physics and Building Ecology).

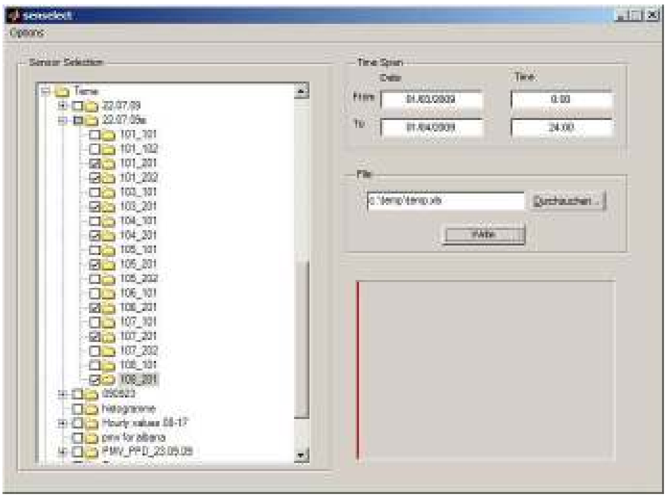


Fig. 13: A graphical user interface of SenSelect

2.6.3 Notepad++

Further, a Notepad ++ application was used to convert the structured data from SenSelect and save as CSV files. For the CSV files, MS Excel was finally used to import the data for a detailed analysis.

2.6.4 Other software

For processing the recorded data, the following software was used: AutoCad, MS Visio, and Matlab for calculating PMV and PPD.

RESULTS

3.1 Overview

This section presents the results of the study in sections. They are split into occupancy, lighting, thermal comfort and interviews.

3.2 Occupancy

Fig. 14 shows the mean occupancy level over the course of a reference day representing the six months monitoring period. The diagram reflects the presence of the occupants at their workspaces and does not take into consideration when occupants are somewhere else within the building. Moreover, Fig. 15 shows the mean occupancy level of a reference day at six different offices. The occupancy patterns in each workstation vary considerably.

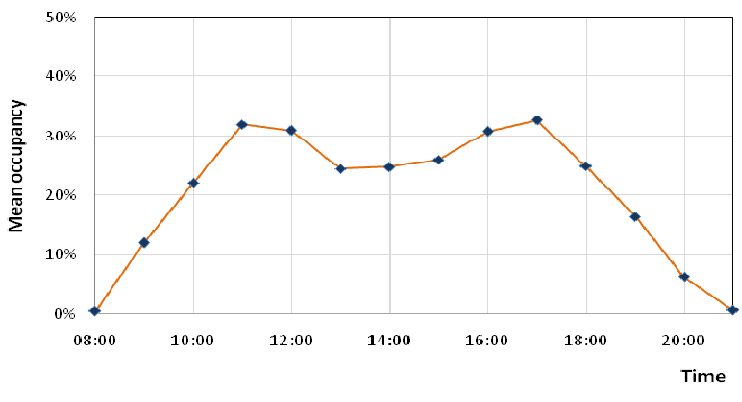


Fig. 14: Mean occupancy level over the course of a reference day (averaged over all workstations observed)

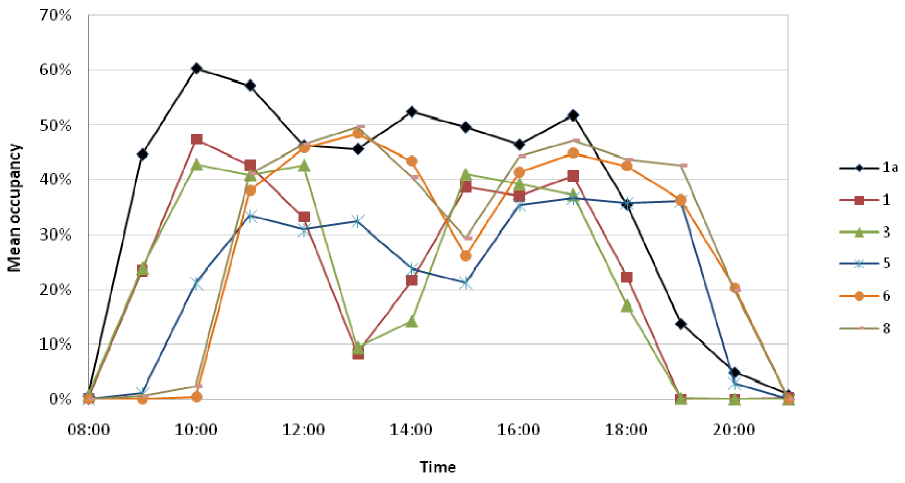


Fig. 15: Observed occupancy levels at 6 workstations over the course of a reference day

Fig. 16 illustrates the mean occupancy level and standard deviation over the course of a reference day for all monitored workstations (six in number).

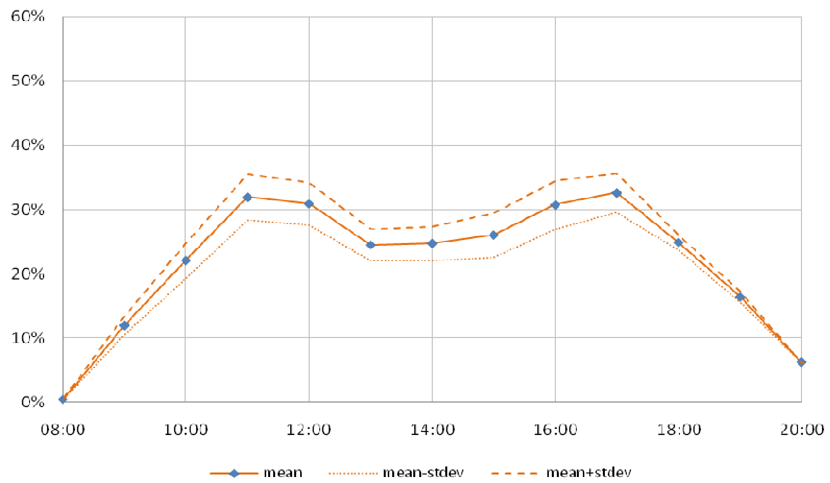


Fig. 16: Mean occupancy level over the course of a reference day (averaged over all workstations observed)

3.3 Lighting

Similar to Hunt (1979), the probability of switching the lights on upon arrival in relation to the working plane illuminance has been explored. Fig. 17 demonstrates the probability that an occupant switches the lights on upon arrival in his/her office as a function of the prevailing task illuminance level immediately before the arrival.

The illuminance range has been divided into bins of 100 lx. For each bin category, the total number of “switching on” events upon arrival has been divided by the total number of events “entering the office” (“switch on” + “remain off” events), expressed in percentage. Thus, the results for each bin (“switch on” probability) have been calculated in percentages with “n” being the “switch on” actions.

The calculated total number of switch-on actions (153) is very low as compared to the observation period of 6 months. This could be related to the occupancy results obtained (30 to 35%) within the study period.

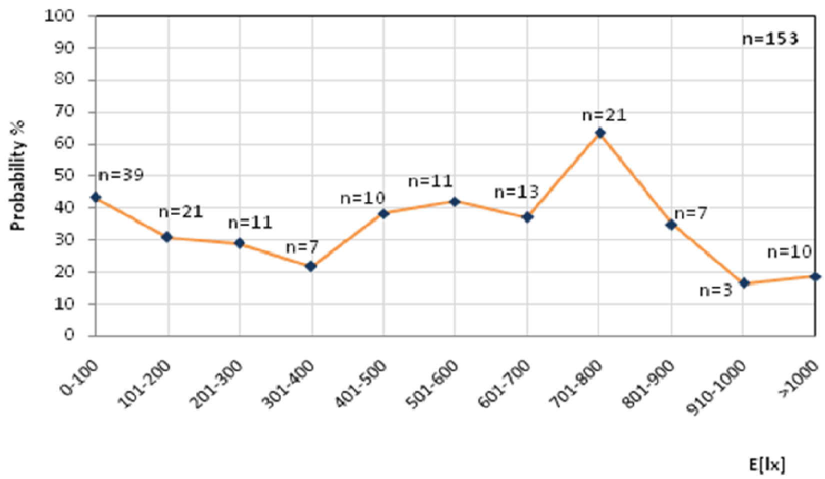


Fig. 17: Probability of switching the lights on upon arrival in the office as a function of the prevailing task illuminance level

Fig. 18 shows the probability of intermediary switching the lights-on by the occupants (15 minutes before and after the switch action) and as a function of the prevailing task illuminance level. In all, 41 switch-on actions could be observed.

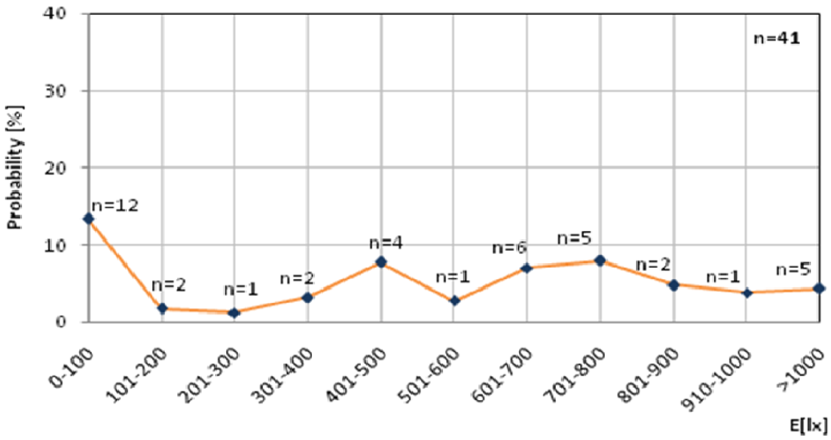


Fig. 18: Probability of intermediary switching the lights-on in the offices as a function of the prevailing task illuminance level

Fig. 19 shows the probabilities of switch-on actions upon arrival and before leaving the offices. In all, there are 243 switch-on actions by the occupants (15 minutes before and after the switch actions) upon arrival and before leaving the offices.

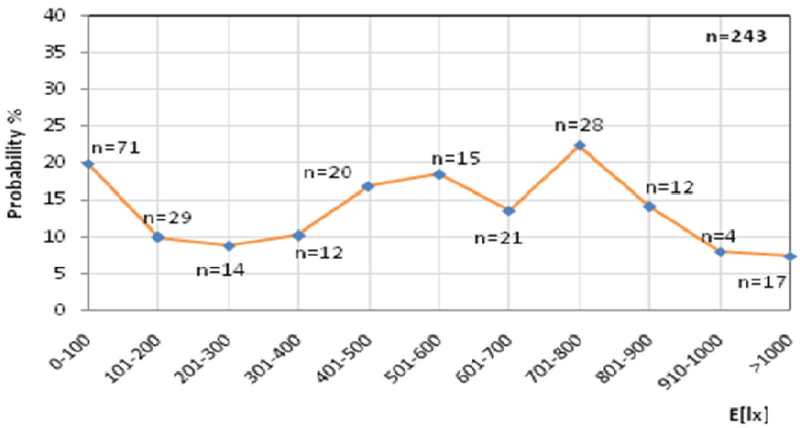


Fig. 19: Probability of intermediary switching the lights on upon arrival in the offices as a function of the prevailing task illuminance level

3.4 Thermal comfort

3.4.1 PMV and PPD

To calculate the thermal sensation in the office spaces, the PMV and PPD approach was used. Here, a scale of <-2 to <+2 was applied. The implication of the values are: -3 cold, -2 cool,-1 slightly cool, 0 neutral, 1 slightly warm, 2 warm, and 3 hot.

Other values used for the approach are:

- Metabolic rate = 1,2 met
- Clothing = 1,0 clo (suits, dresses typical for business people)
- Air velocity = 0,15 m/s

The PPD is a percentage value showing the predicted number of people who would be dissatisfied with the thermal environment.

The following illustrations (Fig. 20 to Fig. 27) show the results of the approach.

Fig. 20 and Fig. 21 show that the workspace at the mezzanine floor performs well. Almost all the data lies within the bins (-1,0) to (0,+1).

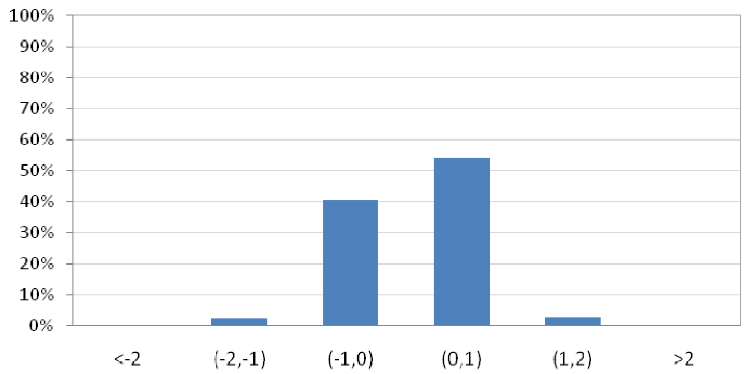


Fig. 20: Distribution of calculated PMV for the office nr.1 at the mezzanine floor

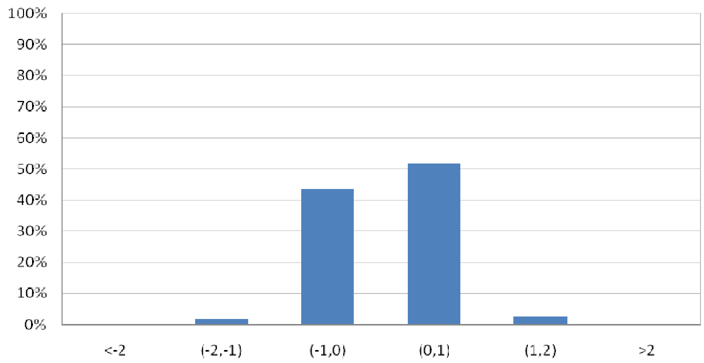


Fig. 21: Distribution of calculated PMV for the office nr.1a at the mezzanine floor

Figs. 22 and 23 suggest that the workspaces on the second floor perform satisfactory (values between -1 to +1). The results are similar to those obtained at the mezzanine floor.

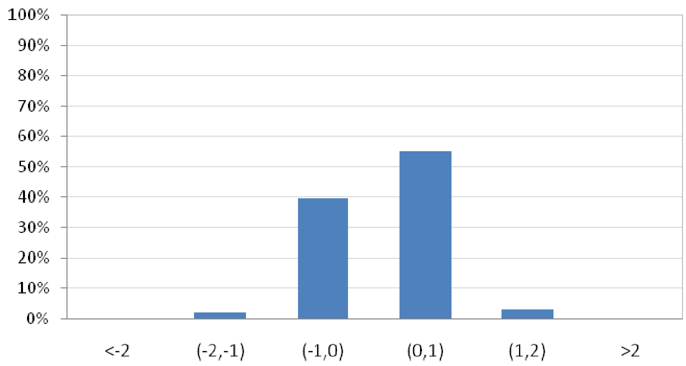


Fig. 22: Distribution of calculated PMV at office nr.3 on the second floor

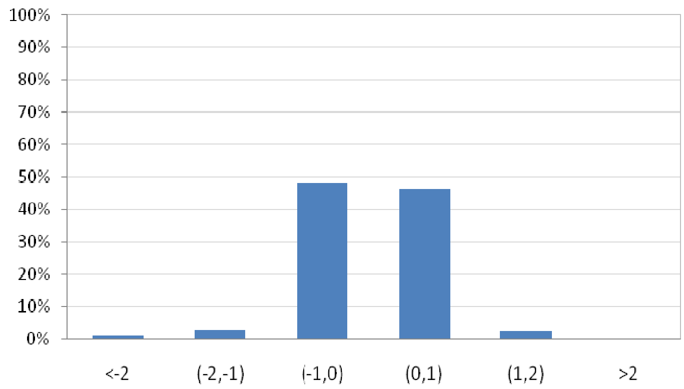


Fig. 23: Distribution of calculated PMV at office nr. 4 on the second floor

There are indications of thermal sensation problems in office number 5 (Fig. 24). Eleven percent of the monitored time (PMV) lies in the 1,2 bin.

Moreover, Figs. 24 and 25 show similar results for office number 5 and 6. However, office number 6 on the seventh floor shows 7% of measured time in -2 and -1 bins

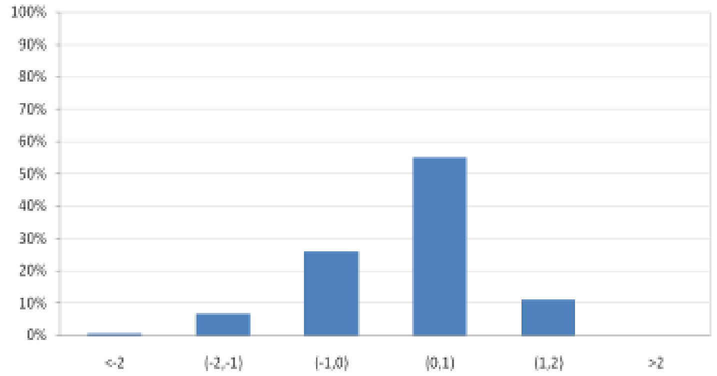


Fig. 24: Distribution of calculated PMV at office nr. 5 on the first floor

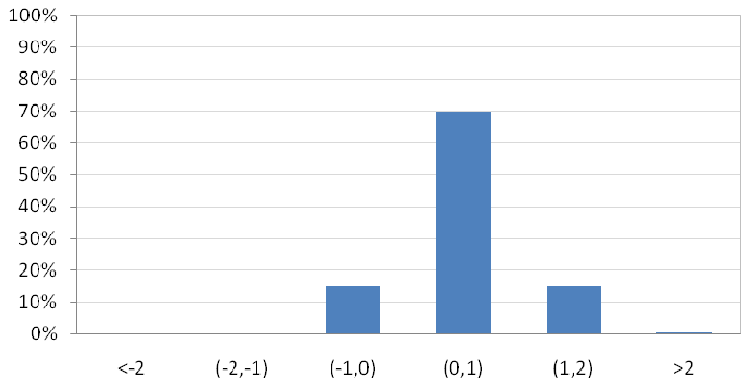


Fig. 25: Distribution of calculated PMV at office nr. 6 on the seventh floor

Fig. 26 and 27 imply that thermal sensation and satisfaction decreases as the floors increase. Thus, the workspaces on the eighth floor show a higher level of dissatisfaction. See Appendix E for other tabulated PMV results.

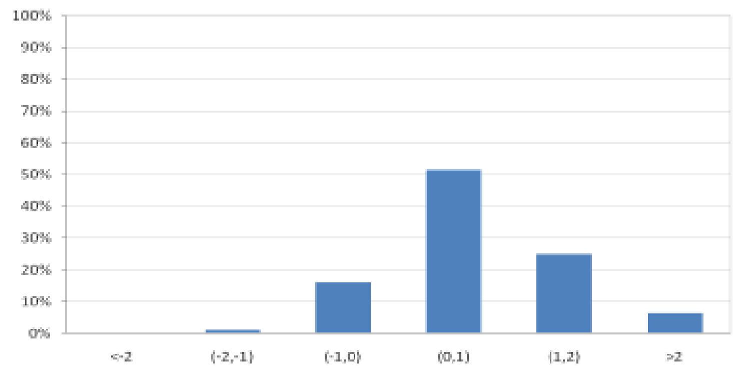


Fig. 26: Distribution of calculated PMV at office nr. 7 on the eighth floor

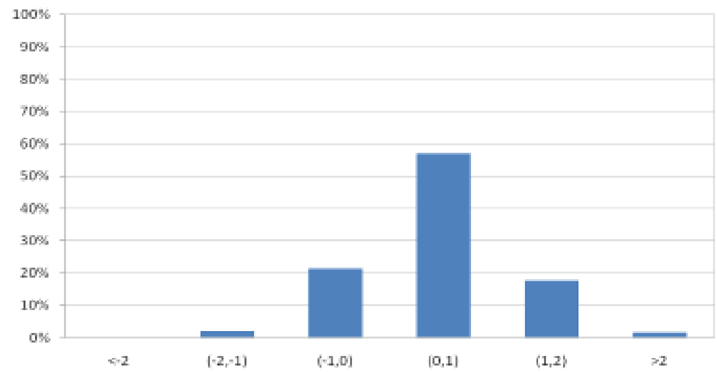


Fig. 27: Distribution of calculated PMV at office nr. 8 on the eighth floor

Fig. 28 shows the calculated PMV during the months of December, January, February and March as well as April, May and June. The diagram shows that the months from April to June are rather warm as compared to the other months. Consequently, the majority of the offices could be said to be performing well since the PMV values are mostly between the -1, 0 and +1 bin.

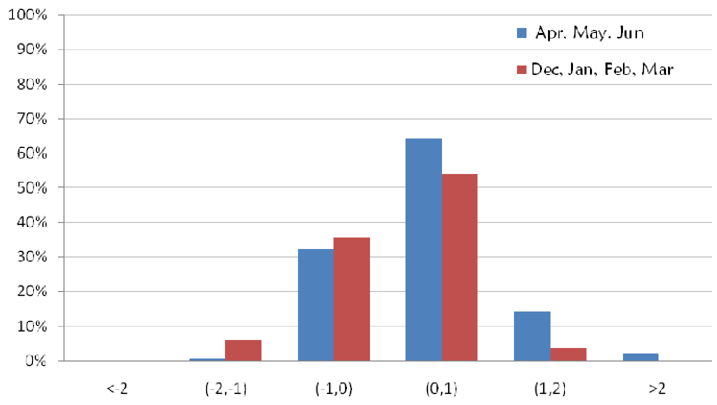


Fig. 28: Mean distribution of calculated PMV in all the offices

Table 1 shows the monthly predicted percentage of dissatisfied for each observed office. The office numbers 6, 7, and 8 show higher PPD values during the warmer months. PPD values in the offices 1, 1a, 3, and 4 are lower.

Table 1: Predicted Percentage of Dissatisfied – PPD [%]

Months	Offices and Orientation								Average
	1	1a	3	4	5	6	7	8	
	N-E	N-E	E	E	S	S-E	N-W	W	
December	11,8	12,8	20,1	18,5	40,1	9,4	14,7	18,1	18,2
January	11,9	11,4	11,5	10,8	18,8	12,0	12,0	12,9	12,7
February	8,7	7,3	8,3	7,4	15,6	27,9	14,2	11,3	12,6
March	9,8	8,1	8,8	9,0	12,1	15,4	16,1	12,9	11,5
April	8,2	8,2	8,2	8,2	12,8	20,2	26,2	21,8	14,2
May	12,8	12,8	12,8	12,8	16,7	40,1	38,4	21,9	21,0
June	7,2	7,1	7,2	7,2	19,4	42,9	41,4	29,7	20,3

3.4.2 Psychometric charts

The tabulated mean hourly values (during the working hours, 8:00 to 17:00) of the measured data were plotted in psychrometric charts.

First, the comfort zone for Kosova needed to be derived (in relation to the neutrality temperature) and plotted on the psychrometric chart.

Here, a method described by Szokolay (2004) based on the aforementioned neutrality temperature was applied. The neutrality temperature is known to be the temperature at which a person should neither feel too hot nor too cold. The range of comfort temperature for 90% acceptability is said to be 2.5°C below and above the neutrality temperature, which depends on the mean monthly outdoor temperature (see Equation. 1).

$$Tn = 17.6 + 0.31 \times To.av \qquad \text{(Eq. 1)}$$

- Tn is the neutrality temperature
- To.av is the mean monthly outdoor temperature

Further, the boundaries of the derived comfort zones (standard effective temperature boundary lines) give the implication that at higher humidity levels, temperature acceptance is reduced (Szokolay 2004, pp. 21 to 22).

Eventually, the monthly comfort zones (December to June) was calculated and the measured temperature and relative humidity values were plotted on the charts. Fig. 29 to Fig. 32 show that the number of working hour observations within the comfort zone is considerably low during the month of June. However, the month of April is comfortable (all points represented in the comfort zone) (see also Table 2). In the month of May, temperature values of less than 20°C were recorded. This was due to the use of installed environmental control systems, orientation of the workspaces and the low occupancy with associated low sensible heat output.

Indoor environmental conditions during the winter months showed very low relative humidity values (ca. 20%) when compared to comfort scale recommendations (see Appendix D).

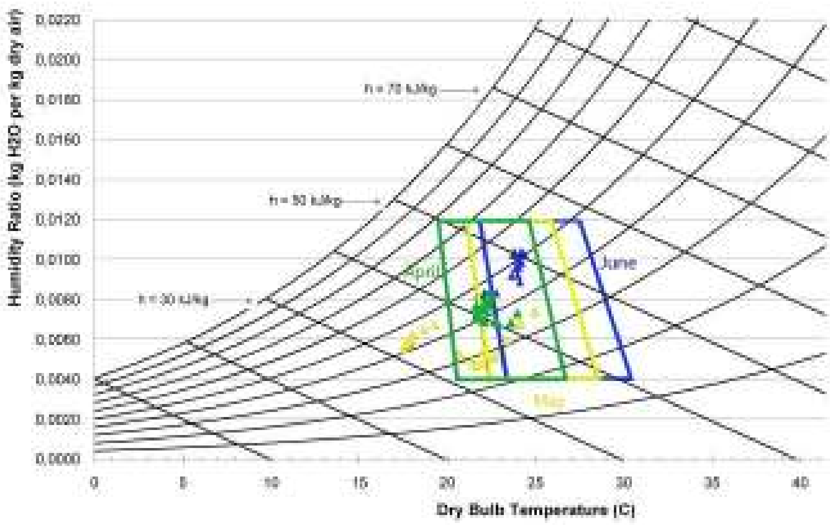


Fig. 29: Hourly indoor temperature and relative humidity values in office nr.1a at the mezzanine floor during the months: April, May, June (8:00 – 17:00)

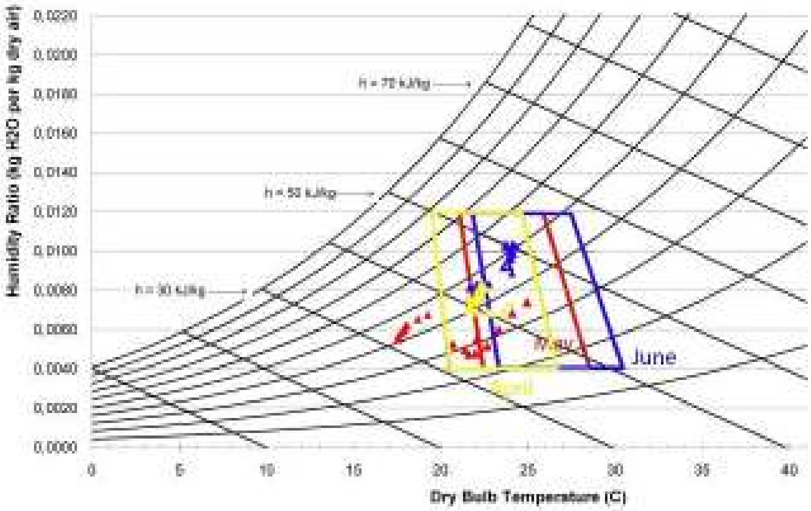


Fig. 30: Hourly indoor temperature and relative humidity values in office nr.4 at the second floor during the months: April, May, June (8:00 – 17:00)

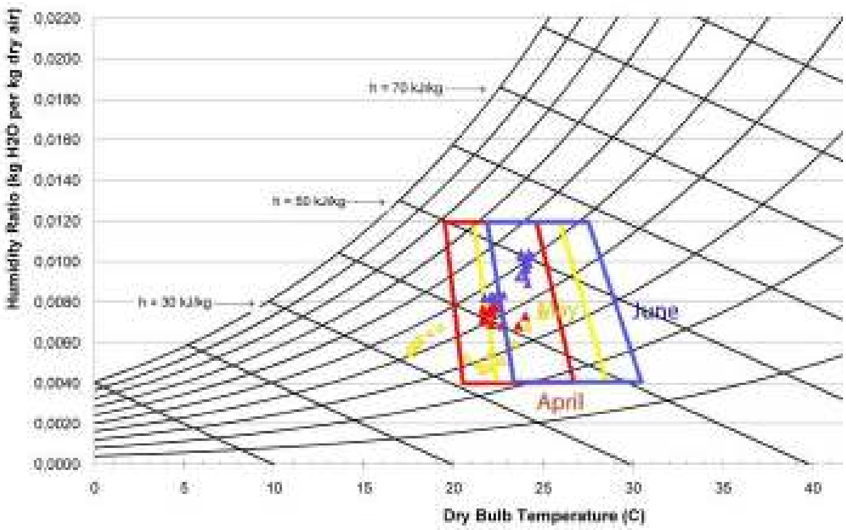


Fig. 31: Hourly indoor temperature and relative humidity values in office nr.7 at the eighth floor during the months: April, May, June (8:00 – 17:00)

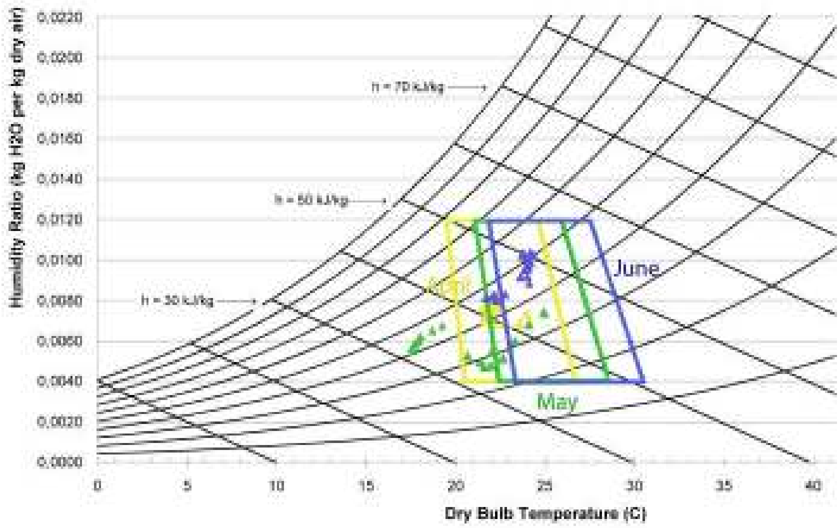


Fig. 32: Hourly indoor temperature and relative humidity values in office nr.8 at the eighth floor during the months: April, May, June (8:00 – 17:00)

For other results on the psychometric charts, please see Appendix D

Table 2 shows for the warmer months of the year, the percentage of the time when indoor conditions could be considered to be within the thermal comfort zone.

Table 2: Percentage of hours within the comfort zone [%]

Months									Average
	1	1a	3	4	5	6	7	8	
April	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	**100,0**
May	64,8	64,8	63,0	65,0	64,2	65,9	49,8	65,1	62,8
June	48,0	48,0	51,0	51,0	46,9	48,3	48,3	44,0	48,2
Average	**70,9**	**70,9**	**71,3**	**72,0**	**70,4**	**71,4**	**66,0**	**69,7**	

3.5 Interviews

This part of the results present the outcome of the interviews. The questionnaire was structured into sections covering the following:

1. Personal inormation about the occupants
2. Evaluation of indoor climate and control systems
3. Operation of and accessibility to system and system controls
4. Awareness of the functionality of the building control systems
5. Personal preferences / health complaints

Table 3 Summary of the questionnaire and the interview results

Summary of the questionnaire and the interview results			
Question		Category	%
1.	Personal information		
1.1	Gender	M F	63 37
1.2	Age	25-35 years 36-45 years 46-55 years >55 years	59 19 12 0
1.4	Occupation	Administrative Assistant Program officer Training Coordinator Legal officer Lawyer National program officer Economist ICT Assistant Inventory clerk Senior Adviser	19 13 19 13 6 6 6 6 6 6
1.5	How many hours in average do you work per week?	51-60 hours 41-50 hours 31-40 hours 21-30 hours 11-20 hours	0 0 69 25 6

1.6	Of these, how many hours do you spend at your workstation?	11-20 hours 21-30 hours 31-40 hours 41-50 hours 51-60 hours	6 44 50 0 0
1.7	What percentage of your work do you perform on computer?	11-20 % 21-30 % 31-40 % 41-50 % 51-60 % 61-70 % 71-80% 81-90%	0 0 0 6 13 6 31 44
1.8	How long have you been working in your current office?	<6 months 7-12 months 13-24 months 25-36 months 36-60 months 61-120 months 121-180 months >180 months	19 19 31 0 13 12 6 0
2.	Evaluation of the indoor climate and environ. control systems		
2.1	How do you find the air quality in your office?	Very bad Bad It's OK Good Very good	0 6 56 38 0
2.2	Are you satisfied with the possibility to ventilate your office?	Not at all Less satisfied It's OK Satisfied Very satisfied	0 25 38 31 6
2.3	How is the average temperature in your office in winter?	Cold Cool Neutral Warm Hot	0 0 50 50 0
2.4	How is the average temperature in your office in summer?	Cold Cool Neutral Warm Hot	6 38 31 19 6
2.5	How satisfied are you with the heating system in your office?	Not at all Less satisfied It's OK	0 6 44

		Satisfied Very satisfied	50 0
2.6	How satisfied are you with the air-conditioning in your office?	Not at all Less satisfied It's OK Satisfied Very satisfied	6 31 6 44 13
2.7	Do you have sufficient daylight in your office?	Not sufficient Could be more It's OK A bit too much Too much	0 25 44 25 6
2.8	Are you annoyed by direct sunlight at your workstation?	Frequently Occasionally Rarely Never	0 44 44 13
2.9	Are you annoyed by reflections or too bright surfaces on your computer screen?	Frequently Occasionally Rarely Never	0 25 50 25
2.10	Do you have sufficient artificial light in your office?	Not sufficient Could be more It's OK A bit too much Too much	0 6 81 0 13
2.11	Are you annoyed by noise in your office?	Frequently Occasionally Rarely Never	0 25 69 6
2.12	Evaluate the distance of your workstation from the window.	Too close It's OK Too far	38 56 6
2.14	Do you have enough privacy in your office to work undisturbed?	Yes It's OK No	13 56 31
3.	Operation and accessibility of the systems and system controls		
3.1	Can you open the windows of your office if required?	Not at all Complicated It's OK Easy Very easy	0 25 13 44 19
3.2	How important is it for you to have the possibility to open the windows?	Unimportant Not so important Don't know Important Very important	0 0 0 56 44

3.3	Can you decide independently when to open/close the windows in your office or do you have to negotiate with other people	No Yes	62 38
3.5	How important is it for you to have the possibility to operate the internal shades?	Unimportant Not so important Don't know Important Very important	
3.6	Can you decide independently when to operate the internal shades in your office or do you have to negotiate with other people?	No Yes	50 50
3.7	Is the light switch easily accessible to you?	Not at all Complicated It's OK Easy Very easy	0 13 37 31 19
3.8	Can you decide independently when to switch on/off the light in your office or do you have to negotiate with other people?	No Yes	50 50
3.9	Is the thermostat easily accessible to you?	Not at all Complicated It's OK Easy Very easy	31 13 13 31 13
3.10	Can you regulate the temperature on your own or do you have to negotiate with other people?	No Yes It's not possible	31 38 31
4. Awareness of the functionality of the building control systems and energy conscious behaviour			
4.1	Are you sufficiently informed about how the following systems (heating, ventilation, cooling, lighting) work in your office? Heating	Not sufficient It's OK Very good	19 38 38
	Ventilation	Not sufficient It's OK Very good	50 19 31
	Air-conditioning	Not sufficient It's OK Very good	6 38 38
	Lighting	Not sufficient It's OK Very good	6 50 38

4.2	Have you ever had a training concerning the systems in your office? If „no“, would you be interested in such a training	No Yes No Don't know Yes	100 13 62 25
4.3	To whom do you refer in case of a problem with the building systems (heating, lighting, etc.)?	BMS	100
4.4	Are you satisfied with the system services and support in your office?	No Don't know Yes	6 63 31
4.5	Do you think that you can influence building energy consumption through the way you operate building systems?	No Don't know Yes	0 62 38
4.6	Do you think about energy conservation when you operate building systems?	No Don't know Yes	25 25 50
5. Personal preferences of organizing the current / ideal working space; health complaints			
5.1	Are you satisfied with the possibilities you have to personalize your working place (furniture, plants, photos…)?	Not at all Less satisfied It's OK Satisfied Very satisfied	6 6 38 44 6
5.2	Generally, how do you find your office climate?	Poor Not so good It's ok Good Very good	0 0 63 31 6
5.3	Which improvement measures in your office would you consider as most urgent?	Bigger office Better air quality Replacement of carpet Quietness and privacy	12 38 19 31
5.4	Do you have any health complaints?	Backache Headache General fatigue Nasal irritation Eyestrain or –burning Respiratory problems Sore throat Neck pain	25 19 19 13 31 13 6 6

3.5.1 Personal information

This section illustrates the outcome of the questions in relation to personal information about the occupants.

Fig. 33 shows the percentage of occupants (male and female), while Fig. 34 shows the ages of the interviewed persons. Most of the interviewees were between the ages of 25 and 35.

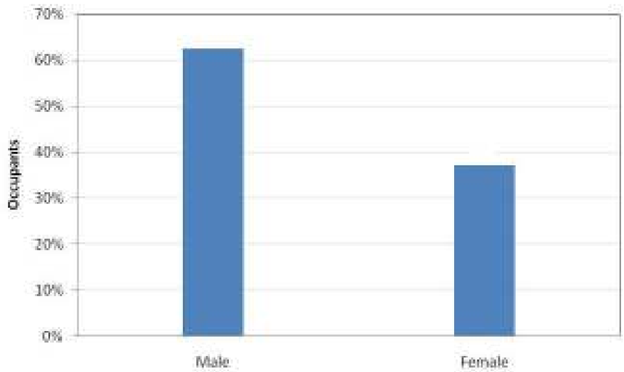


Fig. 33: Gender of interviewed Persons (1.1)

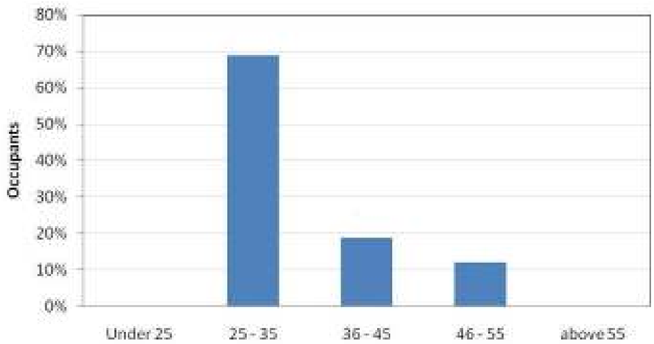
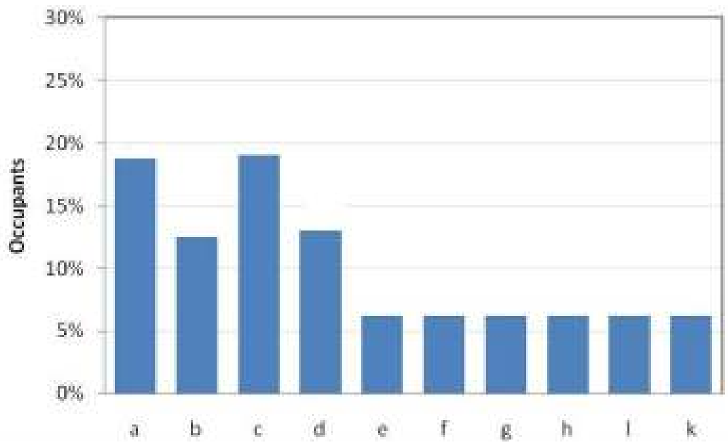


Fig. 34: Age of interviewed Persons (1.2)

Fig. 35 shows the nature of work of the occupants in percentage. Most of the workers interviewed were administrative assistants or training coordinators.



a. Administrative assistant
b. Program officer
c. Training Coordinator
d. Legal Officer
e. Lowyer
f. National program Officer
g. Economist
h. ICT Assistant
i. Inventory Clerk
k. Senior Adviser

Fig. 35: Percentage of occupants and their occupation (1.3)

Fig. 36 shows the working hours of the occupants per week. Most of the workers have a 40 hours per week schedule.

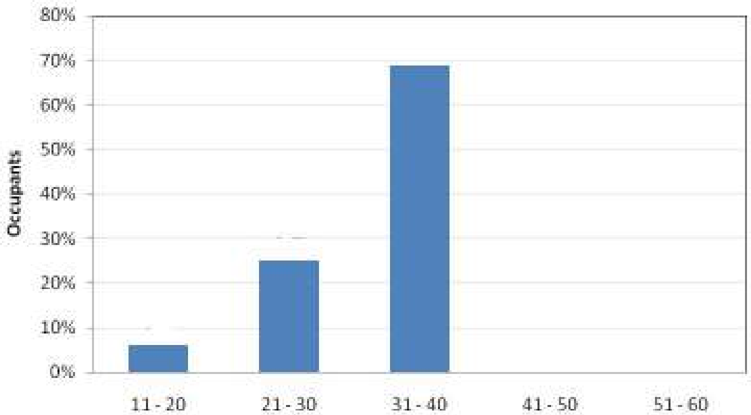


Fig. 36: Average working hours per week (1.4)

The percentage of occupants who spend all their working time at the workstation and the percentage of working hours spent on computers is illustrated in Fig. 37 and 38.

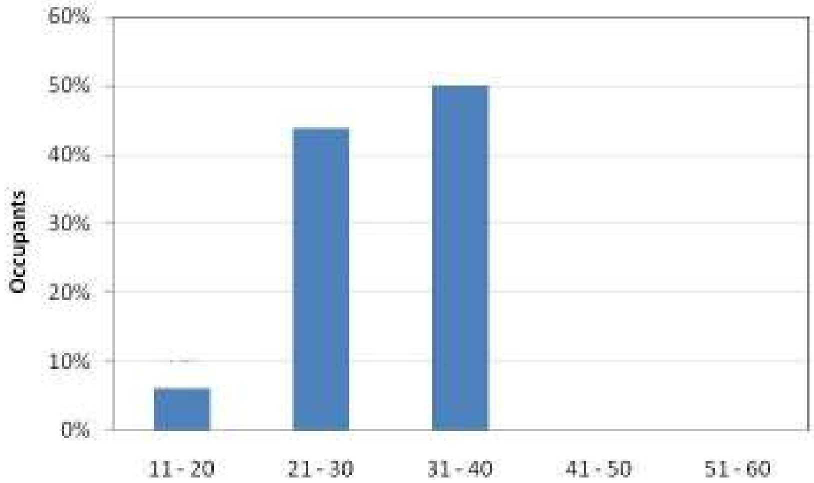


Fig. 37: Working hours at the workstations (1.5)

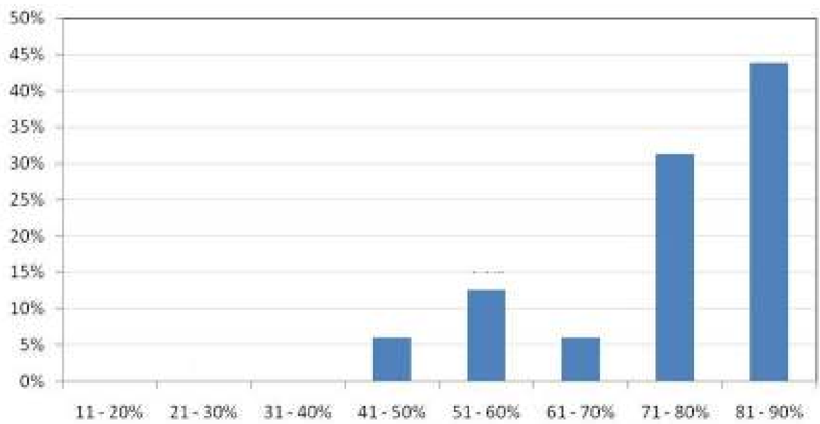


Fig. 38: Percentage of computer work (1.6)

Fig. 39 shows the percentage of occupants and how long they have been working in their current offices.

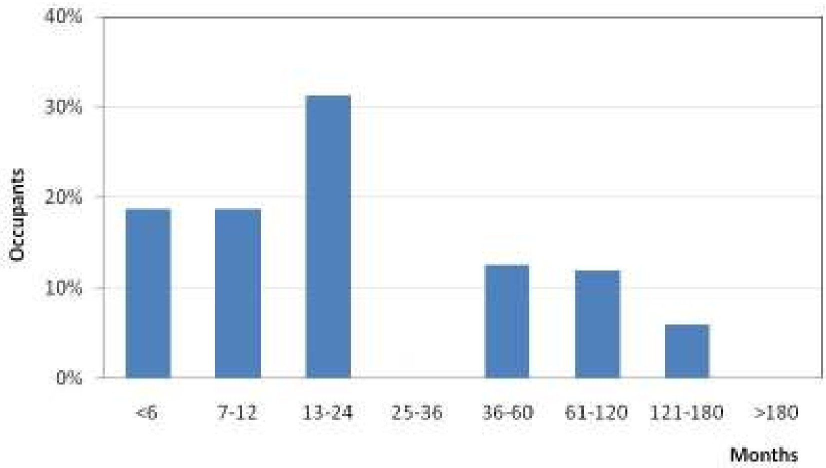


Fig. 39: Working period in the current office (1.7)

3.5.2 Evaluation of indoor climate and control systems

The results of the questions 2.1 – 2.14 are summarized below.

Fig. 40 shows the percentage of occupants and their ranking of the perceived air quality. Most of the occupants have a positive view of the air quality.

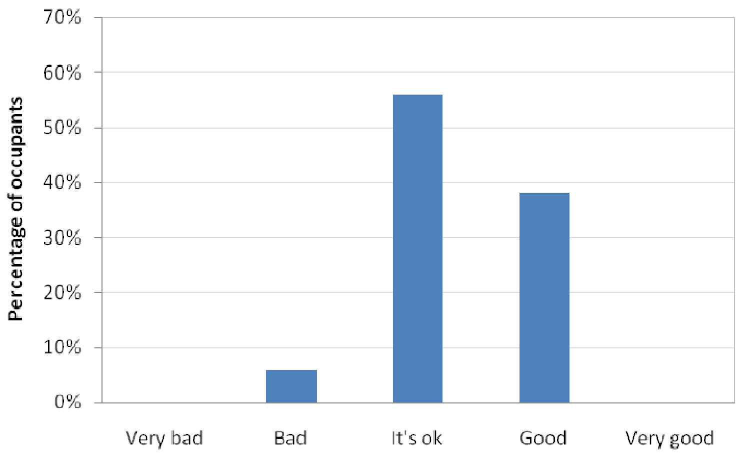


Fig. 40: Assessment of air quality in the office (2.1)

Fig. 41 shows the percentage of occupants and their satisfaction with available ventilation possibilities.

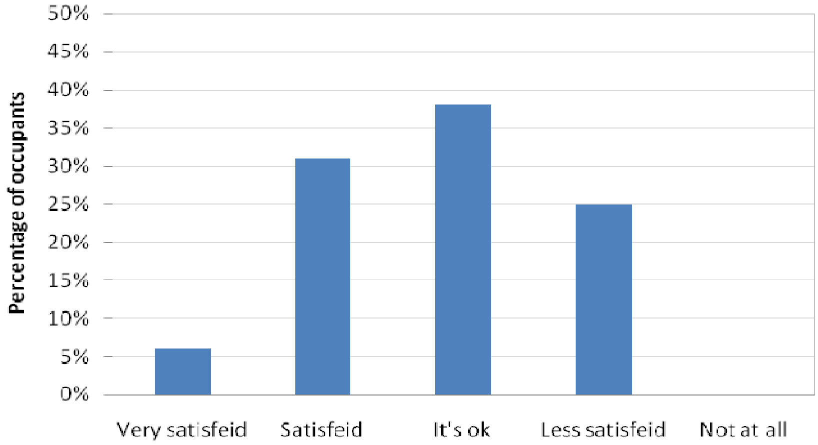


Fig. 41: Satisfaction with the possibilities to ventilate the office (2.2)

The vote on perception of temperature during the winter and summer seasons (Fig. 42).

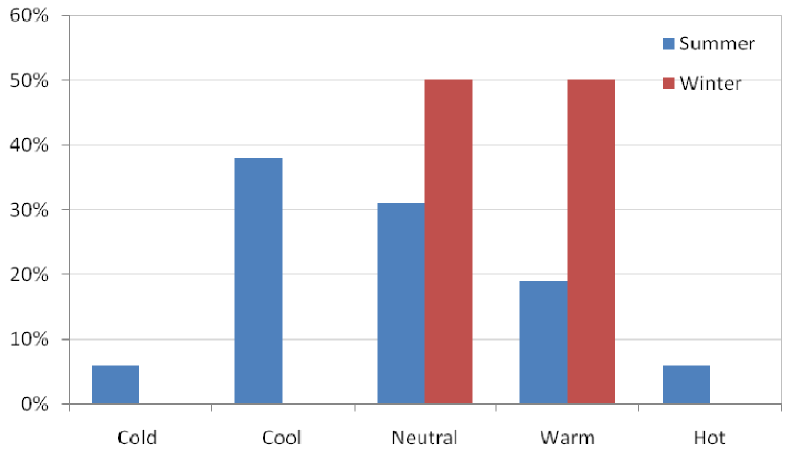


Fig. 42: Assessment of the average temperature in the offices in winter and summer (2.3 and 2.4)

Figs. 43 and 44 shows the percentage of occupants and their evaluation of the thermal control systems.

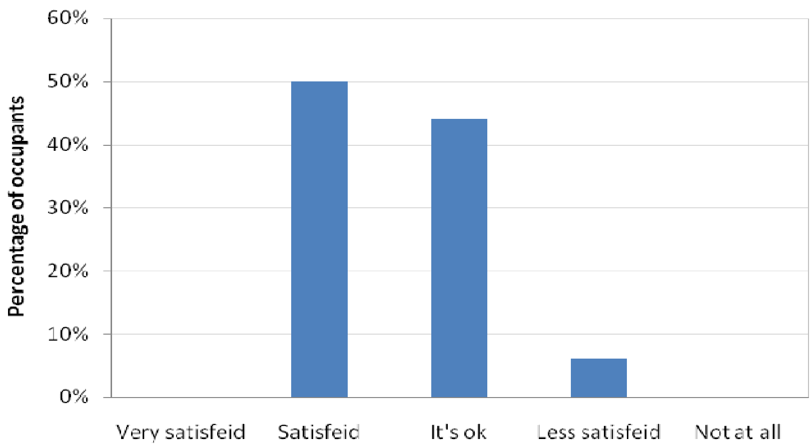


Fig: 43: Satsifaction with the heating system in the office (2.5)

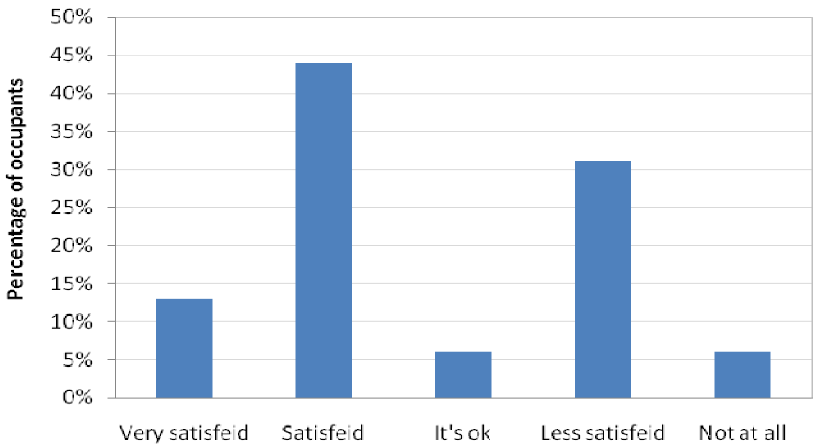


Fig. 44: Satsifaction with the air-conditioning system in the offices (2.6)

Building occupants' view on suffiency of day and artifical lighting are shown in Fig. 45.

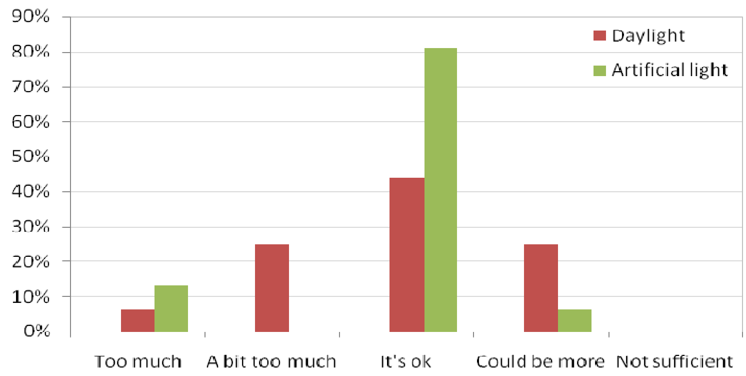


Fig. 45: Sufficiency of day and artifical lighting in the office (2.7 and 2.10)

The percentage of occupants who were annoyed by direct sunlight and reflections on their computer screens are plotted in Fig. 46. The plot also shows the frequency of annoyance in the offices.

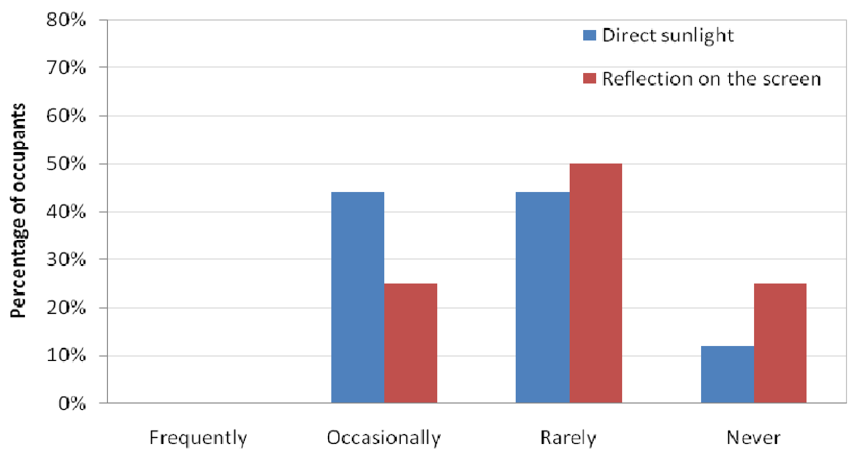


Fig. 46: Occurrence of direct sunlight and reflection on the computer screen (2.8 and 2.9)

The percentage of occupants who were annoyed by noise is shown in Fig. 47. The frequency of annoyance is also demostrated.

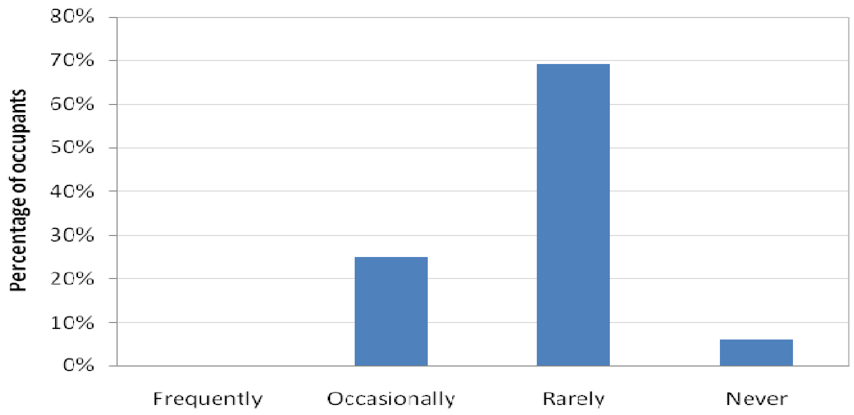


Fig. 47: Noise disturbance (2.11)

The evaluation of the distance from the workspace to the windows is shown in Fig. 48.

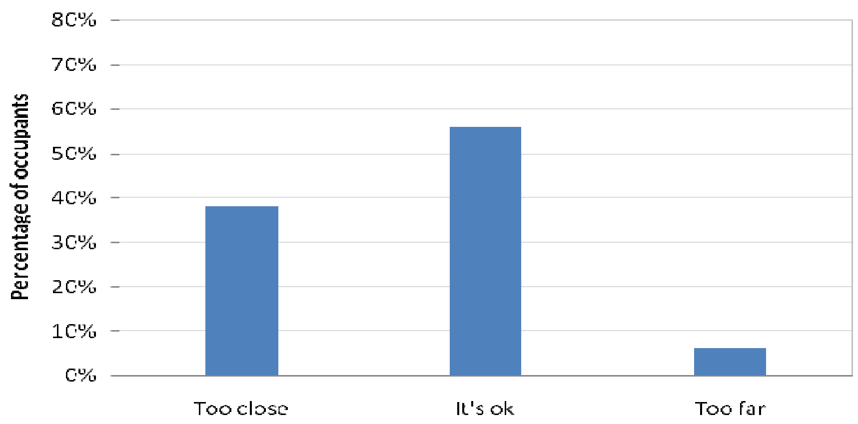


Fig. 48: Evaluation of the distance from the workstation to the window (2.12)

Interviewees' opinion on the possibility to work without disturbances is illustrated in Fig. 49.

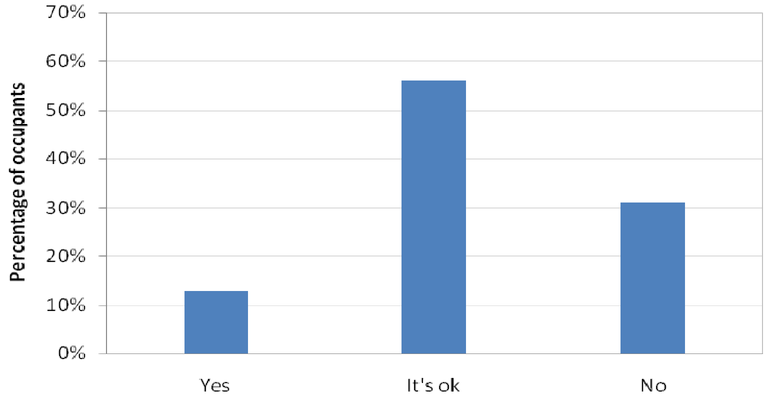


Fig. 49: Possibility to work undisturbed in the office (2.14)

3.5.3 Operation of systems

Results on the operation of systems (question 3.1 – 3.10) are presented below.

Figs. 50 and 51 shows occupants assertion on the possibility and importance attached to the operation of windows. Most occupants were of the view that it is important to have the possibility to operate the windows.

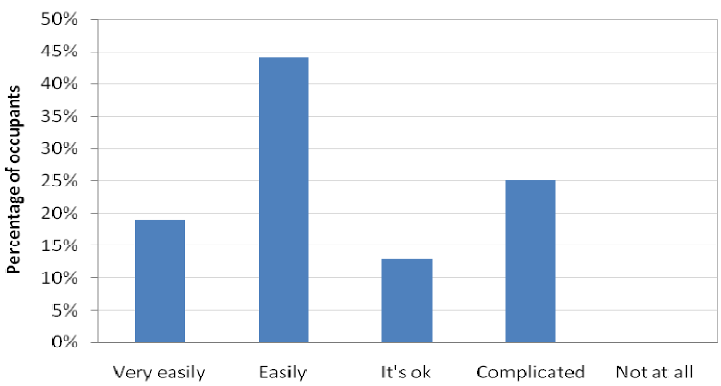


Fig. 50: Possiblity to operate the windows if required (3.1)

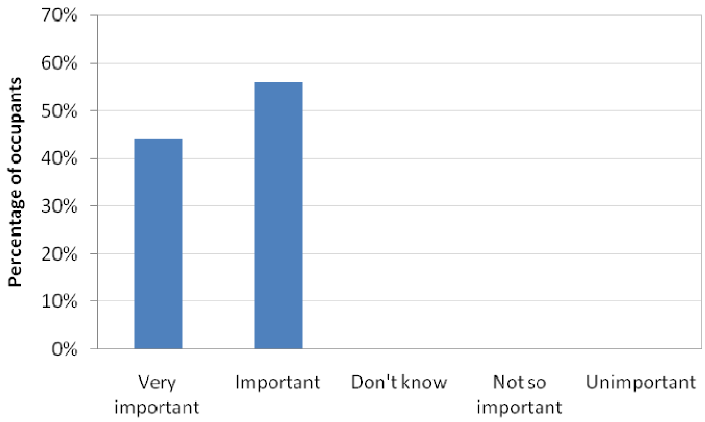


Fig. 51: Importance attached to the possibility of operating the windows (3.2)

Since most of the offices observed were not single occupied, it was of interest to know whether the occupants negotiated with each other before operating the available building systems (windows, fans, AC, lights, etc). The results are outlined in Fig. 52.

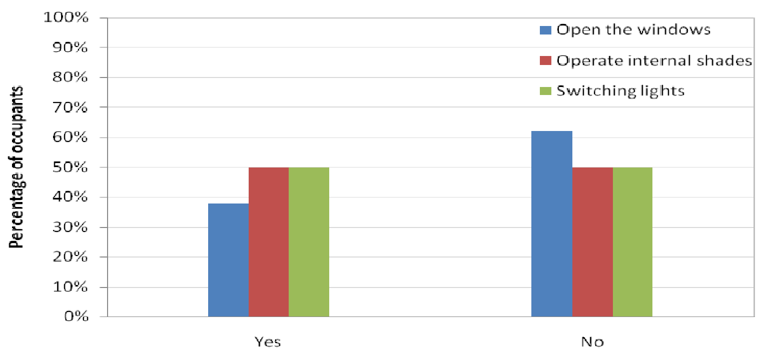


Fig. 52: Possibility to decide independetly when to operate the building systems (3.3, 3.6 and 3.8)

Fig. 53 demonstrates the percentage of the occupants who had the possibility to operate the thermostat (HVAC).

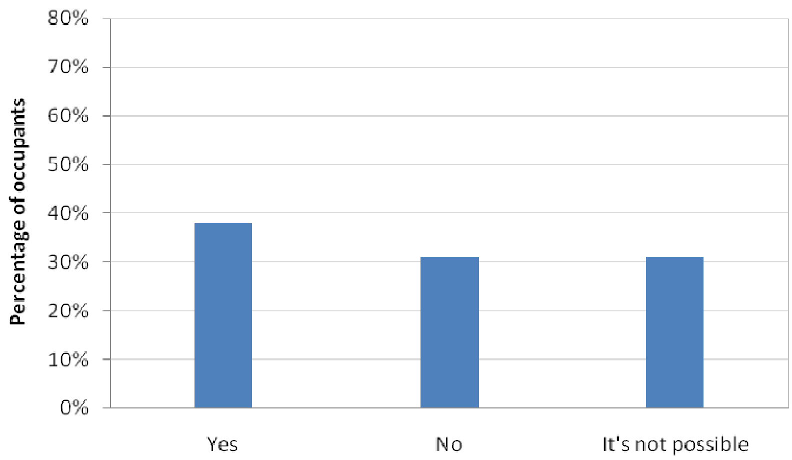


Fig. 53: Possibility to regulate the temperature in the offices (3.10)

Fig. 54 and 55 show the percentage of occupants and their views on the accessibility to the light switch and thermostat. The results show that most of the occupants have easy access to the light switches. The dissatisfied responses could be due to the arrangment of furniture at the workspaces.

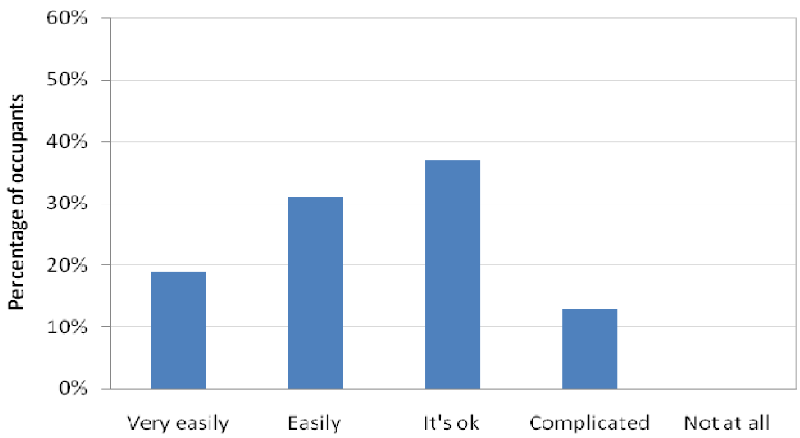


Fig. 54: Accessibility to the light switch (3.7)

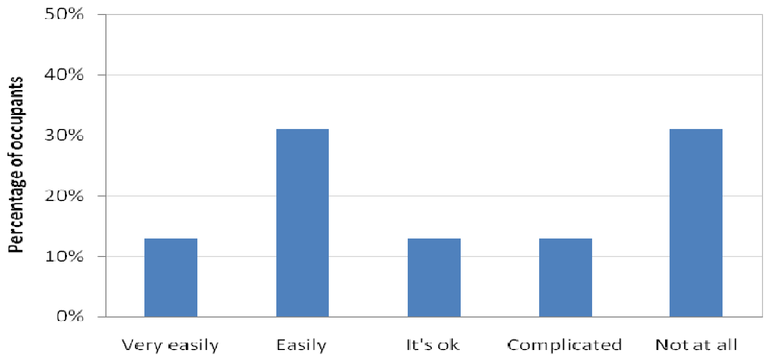


Fig. 55: Accessibility to the thermostat

3.5.4 Awareness on the functionality of the building control systems

Summarized below are the results to the questions 4.1 – 4.6.

Figure 56 shows that the occupants are well informed about the installed building systems. However, information level with regards to ventilation is lower.

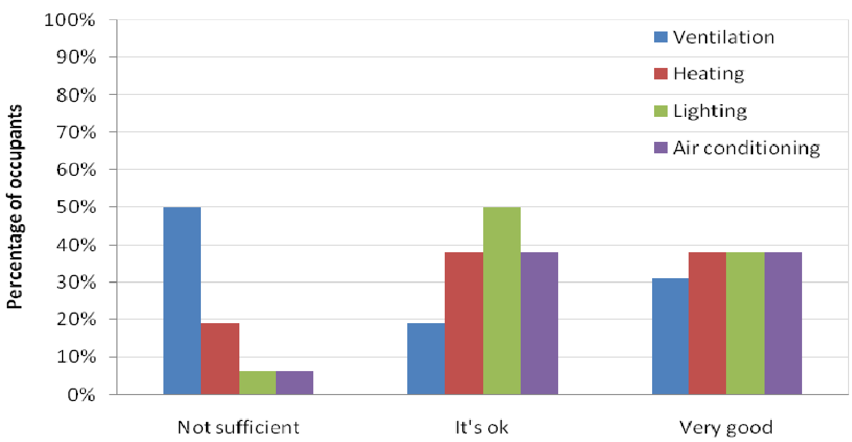


Fig. 56: Levels of information about the building systems (4.1)

Fig. 57 shows the percentage of occupants who were interested in receiving training on building systems. Over 60% could not make a decision on the subject matter. The large number of occupants who were satisfied with the building systems gives an indication of a well functioning BMS (Building Management System), which is also the reference point in case of problems with the systems (Fig. 58).

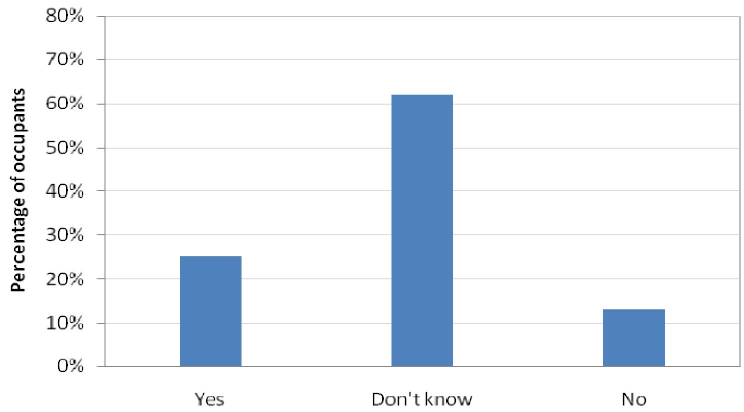


Fig. 57: Occupants interest in receiving training on the building systems.(4.2)

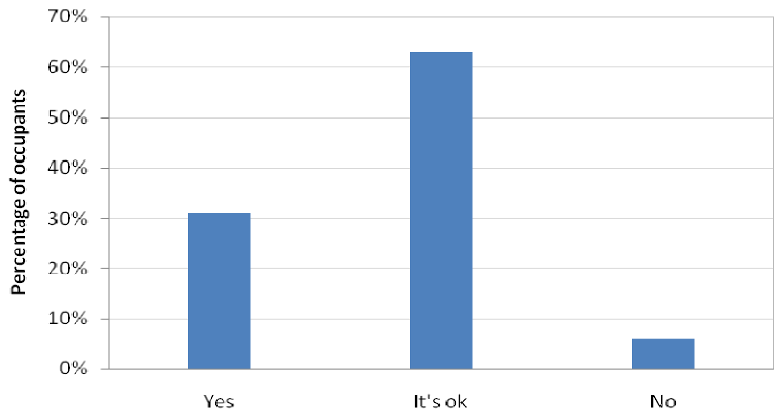


Fig. 58: Satisfaction with the system services in the offices (4.4)

The percentage of occupants who think that they can influence the energy use of the buildings through the operation of the building systems is demonstrated (see Fig. 59), while Fig. 60 considers those occupants who considered energy conservation when operating building systems.

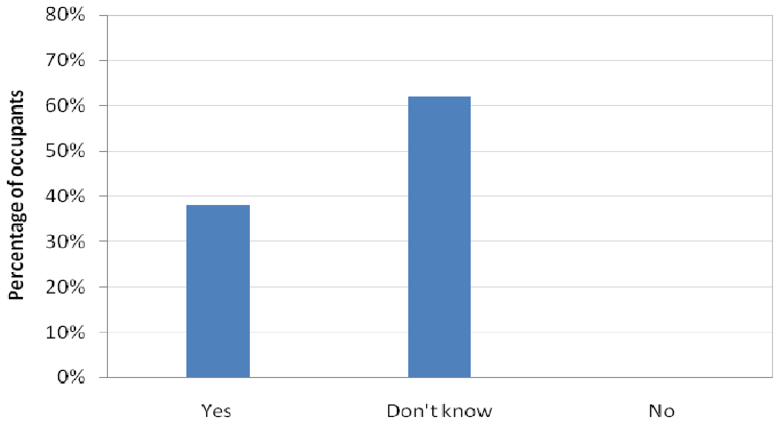


Fig. 59: Influence on building energy consumption from the way people operate building systems (4.5)

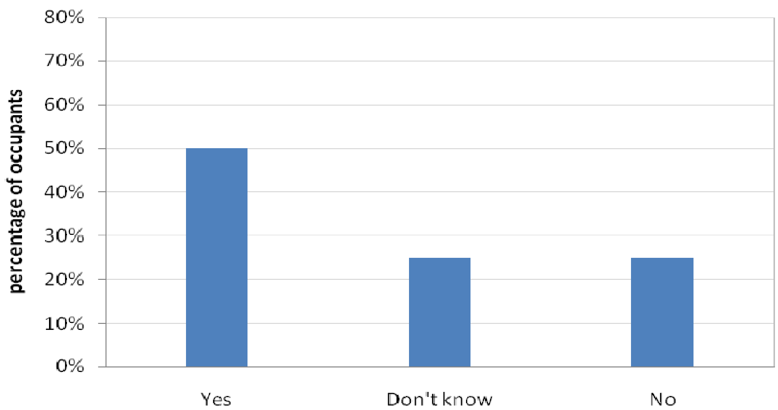


Fig. 60: Consideration of energy conservation aspects when people operate building systems (4.6)

3.5.5 Personal preferences / health complaints

The answers to the personal preference and health issues (question 5.1 – 5.4) are presented in this section.

Fig. 61 shows the percentage of occupants who had a positive view towards personalization possibilities at their workspaces.

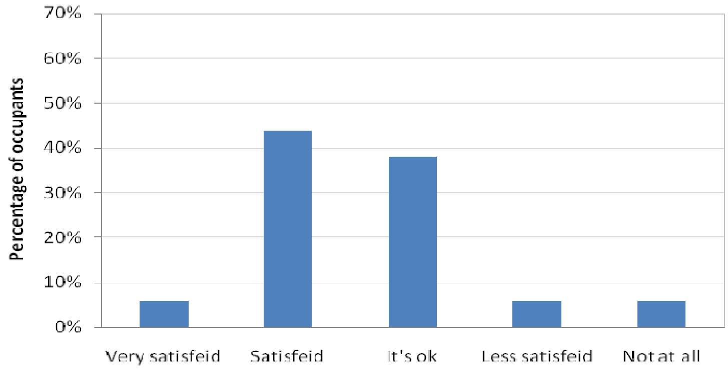


Fig. 61: Satisfaction with the possibilities of workspace personalization

Further, Fig. 62 shows the rank on perception with regards to the office climate.

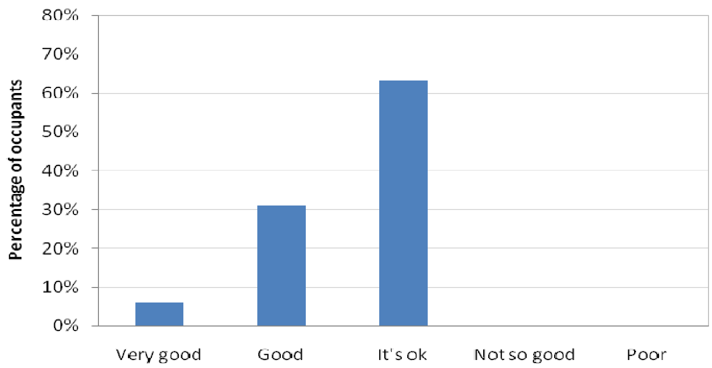


Fig. 62: Occupants vote on office climate

A better air quality was seen as the most important measure needing attention. This gives an indication of dissatisfaction with the air quality by most of the interviewees (see Fig. 63).

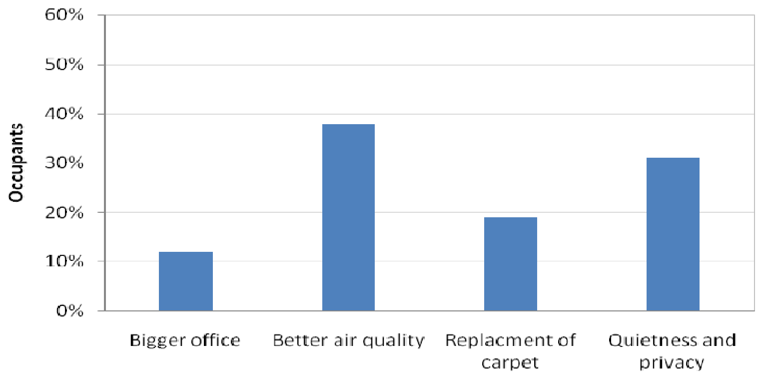


Fig. 63: Votes on urgent improvement measures by the occupants

Fig. 64 demonstrates the percentage of occupants who suffer from diverse health complaints. Eye-strain or burning gives an indication of the low relative humidity levels and the nature of administrative work (working at the computer for many hours).

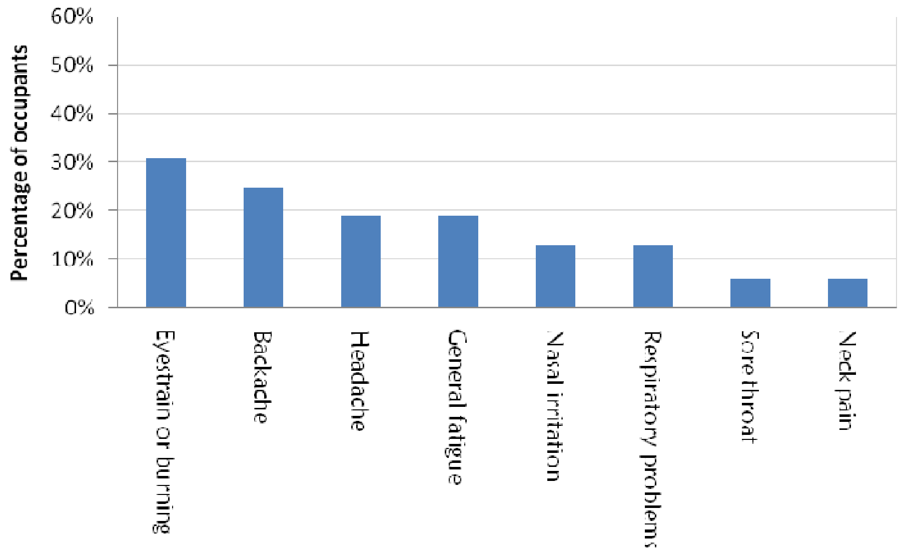


Fig. 64: Frequency of health disorders

4. DISCUSSION

The results of the study are discussed and presented in three sections. They are the behavioural patterns of the occupants in interaction with the building systems, interviews resulting from the questionnaire and the thermal comfort analysis (PMV and PPD).

4.1 Behavior

4.1.1 Occupancy

The occupancy pattern derived from the observation data shows that the offices were not fully used during the working time (8:00 to 17:00 hours). Fig. 14, 15 and 16 demonstrate that the mean occupied hours in the monitored workspaces were 30%.

The low occupancy pattern in the OSCE (The Organization for Security and Co-operation in Europe) building could be linked to the background of the occupants (mostly international with limited contracts). Also, some of the occupants had field missions resulting in the low presence at the workspaces The occupancy value of 30% is in contrast to the result of the study of office buildings in Vienna (mean occupancy of 60%, see Mahdavi, 2007).

Since the measurements at the observed offices showed occupancy of 30 % during the working time, it is not imperative (economically), that the thermal improvement of the building would be necessarily the first measure to enhance its energy efficiency.

4.1.2 Artificial lighting

The behaviour of the occupants with regards to the operation of artificial lighting is presented. The main concern was the frequency of switching-on lights.

The observations regarding the operation of the light switches upon arrival showed that at an illuminance level of 100 lx, the occupants were more likely to switch-on the lights (see Fig. 17 and 18). However, at an illuminance level beyond 700 lx, the probability of occupants switching-on the lights increased (Fig. 64). An illuminance level of 700 lx would have been more than enough for desktop activities (recommended illuminance for office work is 500 lx). The behaviour of the occupants in relation to the use of artificial lighting could be said to be not energy conscious.

The reason for this negative behaviour could be related to direct and reflected solar radiation triggering the operation of shades. For instance, about 30% of the workers interviewed were of the opinion that there was too much daylight at their workspaces. Once the shades were deployed, the occupants resorted to the use of artificial lighting to increase illuminance at the workspaces. Furthermore, partly deployed shades resulted in contrast at the workspaces. This visual discomfort could have led the workers to switch on the lights.

Generally, the absolute numbers of switching actions were low and this could be related to the low occupancy levels in the offices (30%) (Fig. 18 and 19).

4.2 Interviews

The number of respondents to the interviews conducted was eighteen. The general information received showed that most of the occupants were between the ages of 25 and 35 years. Based on self assessment, most of the working time was spent in the offices (Fig. 36 and Fig. 37). However, occupancy data retrieved at the observed workstations contradicts the above assertion (Fig. 14).

On the perception of the interviewees on the prevailing air quality in the offices, most of the occupants were of the view that the quality was good (see Fig. 40). But when asked about the most important measure needing improvement, 38% of the workers voted for the air quality (Fig. 41). A detailed analysis of the data showed that high dissatisfaction was reported by those occupants who could not operate the windows (first floor windows were not operable). The rest of the floors had operable windows and the occupants were also more satisfied with the possibility to ventilate the offices.

Fig. 42 illustrates the satisfaction with temperature during the winter months. Most people interviewed had a positive notion of thermal comfort. About 50% also had a positive view on comfort (cool/cold) during the summer months. Generally, majority of the workers were satisfied with the heating and air-conditioning system (see Fig. 43 and 44).

Asked on the perception of lighting, about 31% of the workers voted for "too much/a bit too much" daylight and the majority was satisfied with artificial lighting (Fig. 45). The outcome on issues in relation to daylight (reflections on computer screens) could be due to the orientation of the workspaces, the glazing quality and distance to the windows (Fig. 46). In addition, a positive view (100% of the occupants) was expressed about the possibility to operate the windows (Fig. 51). This result correlates to other studies on occupants in air-conditioned buildings (especially when windows are not operable).

Most of the workers who answered the set of questions were in multiple occupancy offices and about 50% were satisfied with independently operating the building systems (windows, shades, lights, etc) without negotiations. The majority of workers was of the opinion that the light switches were easily accessible (Fig. 54).

In Fig. 56, the level of information on building systems is expressed. About 50% of the interviewees were not sufficiently informed, knew nothing about training programmes in the building (Fig. 57) and were disturbed about the operation of the ventilation system. This was more evident at the first floor where the windows were not operable.

On questions related to energy conscious behaviour in the operation of building systems, about 38% said that they were aware that control actions could influence energy consumption and about 50% considered energy use when operating the installed systems (Fig. 58 and 59). The assertion of influence on building energy use through the operation of installed systems relates to the results of studies done in office buildings in Austria by Lambeva (2007) and Kabir (2007). Unfortunately, most occupants in the OSCE building were not well informed on behavioural factors to save energy.

The most urgent measure needing attention in the offices was air quality (Fig. 63). This was followed by quietness and privacy. This could be related to the predominantly multiple occupancy nature of the offices in the OSCE building.

About 25% wished for the carpet to be replaced (disturbance by dust). Other disturbances were on health issues (eyestrain or burning, backache, headache and general fatigue, (Fig. 64)) which seem to be frequently reported in office buildings. The measured relative humidity values were low and this could have lead to about 31% of the occupants having eyestrain or burning sensations. Respiratory problems and nasal irritations were less frequently reported.

4.3 Thermal Comfort

4.3.1 Psychometric Charts

To derive and analyse the thermal conditions prevailing in the offices, psychometric charts were used.

Relative humidity in the offices was very low (17 to 18%) (see Appendix D). The reason could be linked to the inefficient central heating system. The occupants also used the installed air-conditioners to heat the workspaces during the winter months. The very low relative humidity values could be related to the 31% of the occupants who had frequent eyestrains as health complaint (Fig. 64). In addition, the adaptive comfort theory on which the comfort zones are based suggests a minimum temperature of 21.5°C as comfortable. The poor performance of the offices during the winter months was a surprise (see Appendix D). Nevertheless, the month of April was satisfactory while the month of May and June were significantly comfortable (Fig. 28). In Table 2, the percentage of working hours represented in the comfort zone is illustrated. Satisfactory values were tabulated for the month of April, May and less satisfactory values for the month of June (higher temperature values were recorded for the month of June).

4.3.2 Predicted Mean Vote - PMV and Predicted Percentage of Dissatisfied - PPD

Using the approach after Fanger (1970), the Predicted Mean Vote (PMV) and the Predicted Percentage of Dissatisfied (PPD) were calculated. Considered assumptions were for normal office work (metabolic rate and clothing values).

Generally, the results show that the monitored offices performed quite well. The offices at the mezzanine and second floors (offices 3 and 4) were thermally better than those at the first and upper floors (see Fig. 20, 21, 22 and 23).

Conditions recorded for the months of April, May and June show higher PMV values, especially in the office numbers 6, 7 and 8 (Figures 65 to 67). These offices also show higher PPD values during the months of April, May and June (see Table 1).

The reason for this result is – in the case of office 7 – most probably the fact that the office was unoccupied most of the time. The reason for this circumstance in offices 6 and 8 is less clear. Sporadic observations indicate, however, that the occupants of the latter offices operated (closed) their shades less frequently. This may have resulted in higher solar gains and thus higher PMV values.

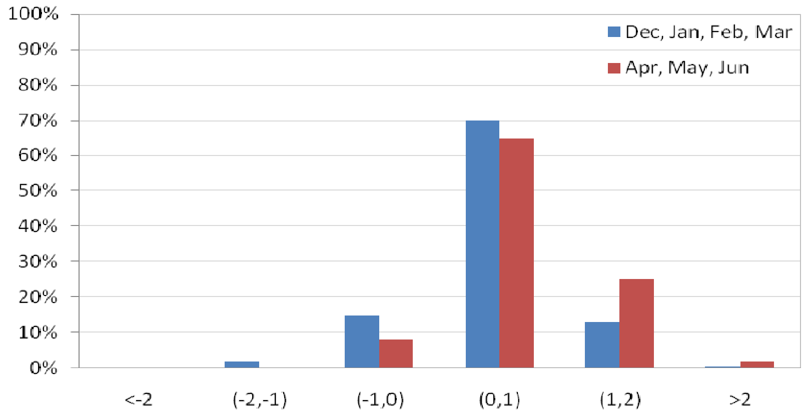


Fig. 65: Distribution of calculated PMV at office nr.6 during the months of December, January, February, March and during the months of April, May, June

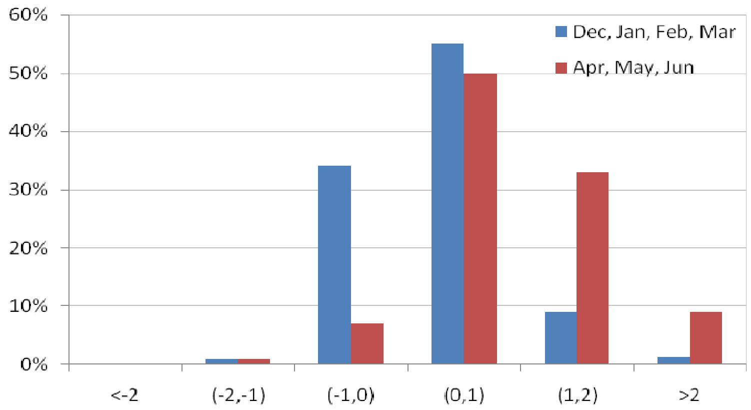


Fig. 66: Distribution of calculated PMV at office nr. 7 during the months of December, January, February, March and during the months of April, May, June

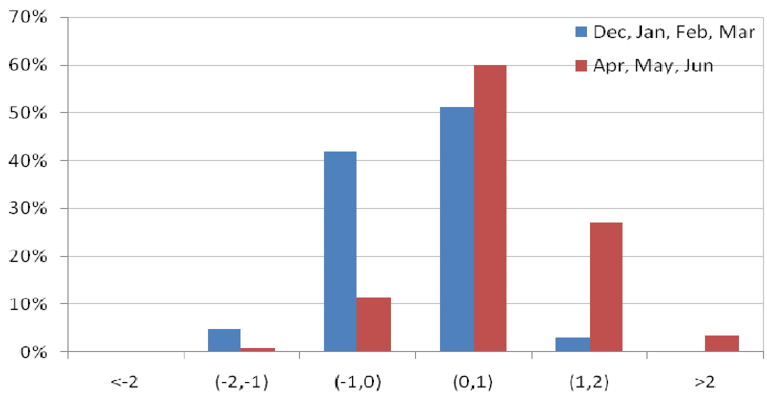


Fig. 67: Distribution of calculated PMV at office nr. 8 during the months of December, January, February, March and during the months of April, May, June

The interviews indicate that the occupants perceived (retrospectively) the winter months as warmer (see Figure 42). However, PMV results suggest a slight shift to higher values in the summer (see Figure 28). This discrepancy might be partially the result of the assumed versus actual clo-values of the occupants. In PMV calculations, a constant clo-value was assumed. In reality, the summer time clo – values could have been much lower.

5. CONCLUSION

Over a period of 6 months, indoor environmental parameters and occupant's behaviour have been monitored in the OSCE building in Prishtina, Kosovo. The empirical study had the aim of contributing to the understanding of user behaviour and thermal performance in office buildings. Presented below are conclusions on the aspects of the study.

5.1 Occupancy/Lighting

The study showed that the workers in the building were not always at their workspaces (30% mean occupancy recorded). This was different from their assertion with regards to presence at workstations. A reason for the low occupancy was due to the short term employment contract and field trips of some of the occupants.

With regards to the probability of switching-on lights, only 153 actions were recorded during the study period. This was rather low and could be due to the nature of work of the occupants and the resulting low occupancy level.

5.2 Thermal Comfort

The study showed that the thermal conditions in the offices were not fully satisfactory. With the exception of April, all the winter months' plots on the psychrometric charts were outside the comfort zone. The relative humidity values recorded were very low (ca. 20%). This may have negatively affected the occupants, as indicated by the interview results (see Figure 64).

5.3 Interviews

Generally, the interview outcome revealed that the occupants were not well informed regarding available building systems and training possibilities. In addition, 62% of the workers did not know whether they could influence building energy consumption through their actions whereas about 50% thought about energy saving aspects when operating the installed systems. Finally, 94% were of the view that the air quality was good but that the most urgent measure needing improvement was the air quality.

5.4 Recommendations

Based on the results of the study, the following is recommended:

- There is the urgent need for facility managers to inform and train occupants regarding building systems and their operation.
- The outcome of the occupancy pattern (30%) indicates a poor usage of the building's spatial resources.
- The very low relative humidity values during the winter months indicate that some humidifation may be necessary.
- The actual building occupancy and use patterns deviate significantly from typical assumptions in simulation studies.
- The building's performance and its energy efficiency could benefit from an intelligent system control strategy (shades, lights, ventilation).

5.5 Future studies

The goal of future studies is as follows:

- A broad monitoring of more office buildings and simulation approach to effectively study and improve the thermal performance and the understanding of user behaviour of administrative buildings in Kosova.
- The development of a basis to evaluate the influence of occupancy behaviour on building energy consumption.
- Creation of strategies to inform building occupants regarding the energy and comfort implications of their control actions.

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7. LIST OF FIGURES

8. LIST OF TABLES AND EQUATION

- Tn is the neutrality temperature
- To.av is the mean monthly outdoor temperature

9. APPENDIX

9.1 Appendix A: Information on data loggers

The information concerning the properties of the sensors used is presented in this section.

Data logger: IT-200

IT-200 loggers were used to log occupancy and state of artificial lighting (on/off) (Fig. A1).

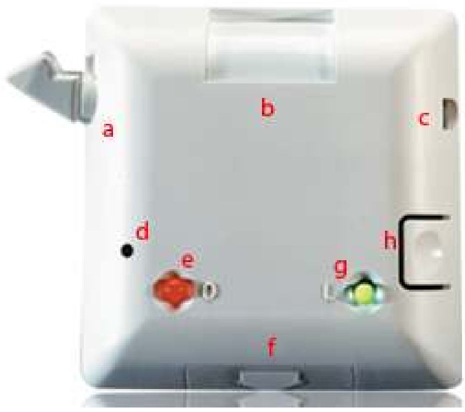

Fig. A 1: Components of sensor IT-200

a. Adjustable light pipe observes lighting level

b. Infrared sensor detects movement of people

c. Button adjusts the sensitivity of the light sensor

d. Reset switch

e. Red LED blinks during occupancy detection

f. Serial port connects to PC

g. Green LED blinks when lighting is detected

h. Test button activates LEDs for 60 seconds during which sensitivity is set and proper location of occupancy detection is verified.

Key specifications:

- Lithium battery operation, average battery life ~10 years, battery life indicator
- Coverage up to 45 m²
- Stores a maximum of 4096 entries
- Connects to computer (PC) for data retrieval via serial connector cable

IT-200 is connected to a computer via a 9-pin serial port and connector cable. The application software package designed for the IT - 200 logger is the ITProSoft. The log data can be saved for future use by the 'Save As' command from the File menu. This command stores the log data as '.XLS' file for further analysis in Excel. Fig. A2 shows the graphical interface of ITProSoft.

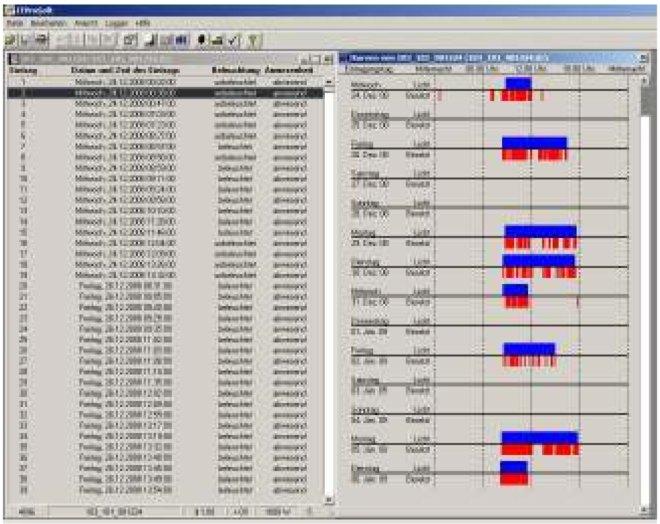

Fig. A 2: Graphical Interface of ITProSoft

Data logger: HOBO U12-012

Temperature, relative humidity and light intensity values were measured using Hobo data loggers (Hobo U12-012) placed approximately near to the workstations.

Fig. A 3: Components of sensor/logger

1. Relative humidity/temperature sensor
2. Reset button
3. USB port
4. LED operation indicator
5. Illuminance sensor

The HOBO data logger is connected to a computer using a USB cable (USB port and connection cable). A software (GreenLine) is used to launch the sensor, read out the data, and analyse the status of the logger. Fig. A4 shows the interface of the GreenLine software. The software saves recorded data as “Hobo” file which can eventually be exported to MS Excel for a detailed analysis.

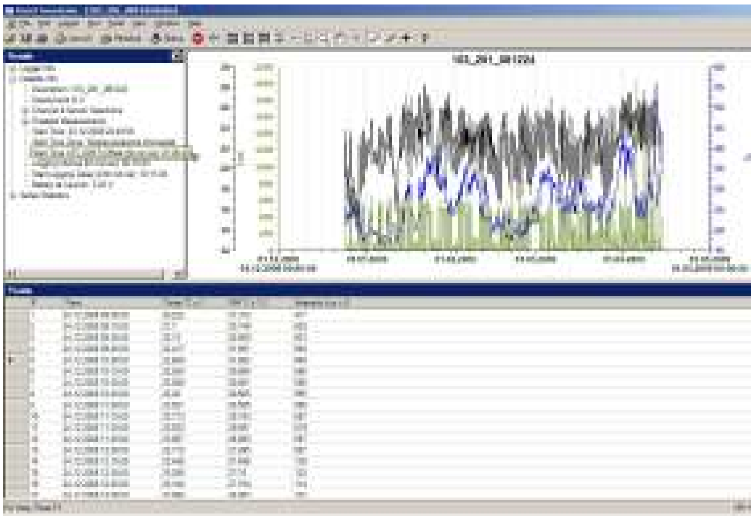

Fig. A 4: Graphical Interface of GreenLine

9.2 Appendix B: Architectural Drawings of the OSCE building

Presented below are schematic plans of the OSCE building (Fig. B1 to B4, provided by Teuta Jashari) which was used in the study.

Fig. B1 to B4 show the schematic floor plans of the (shaded area are the 7 monitored workspaces) building.

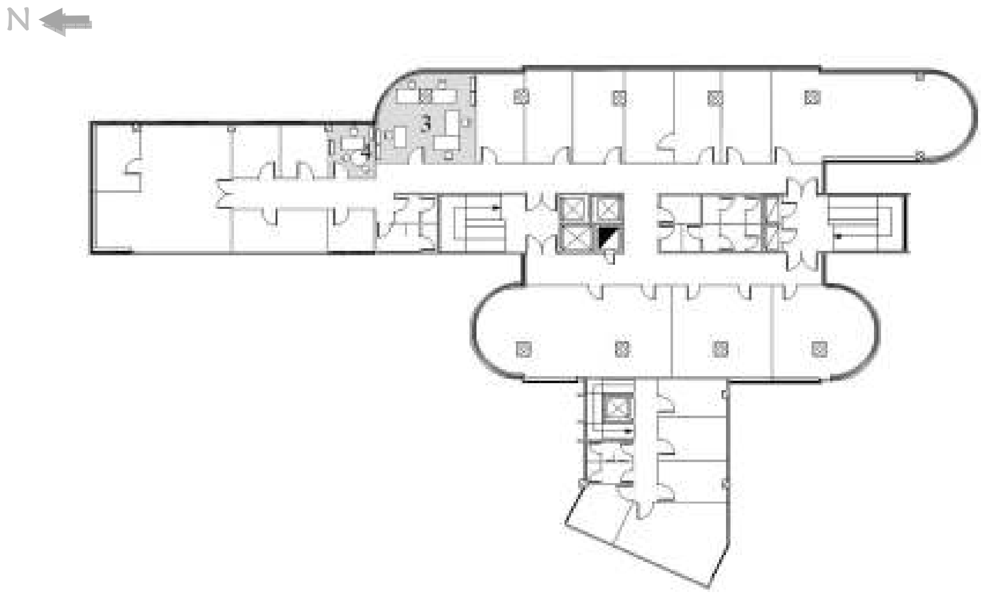

Fig. B 1: Schematic plan of office nr. 3 and 4 on the second floor (east oriented)

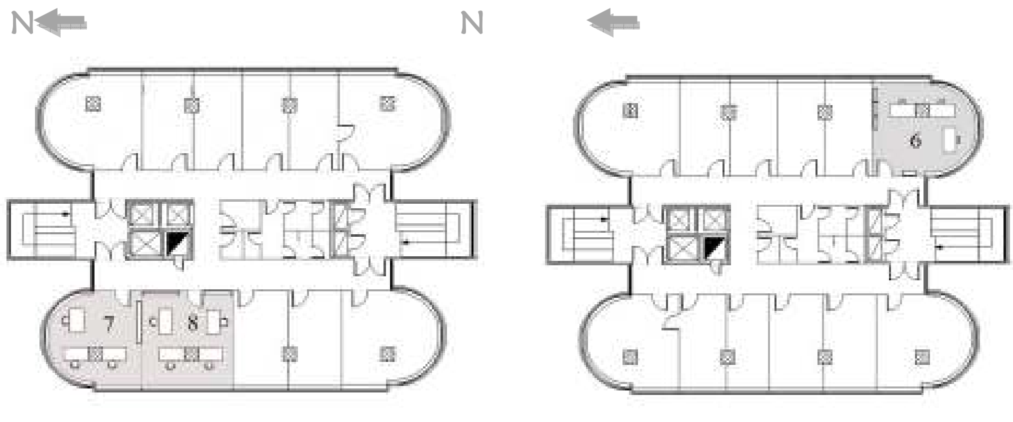

Fig. B 2: Schematic plan of office nr. 6 on the seventh floor with a south-eastern orientation (Right) and office nr. 7 and 8 on the eighth floor oriented towards the north-west (Left)

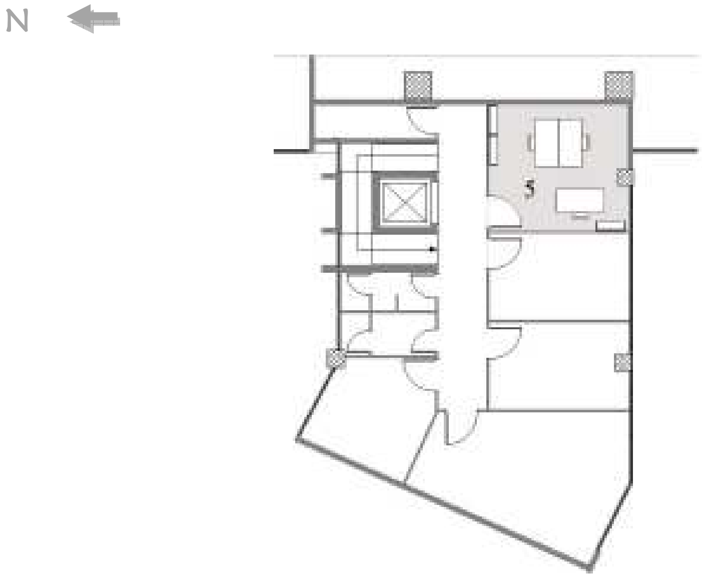

Fig. B 3: Schematic plan of office nr. 5 on the first floor (south oriented)

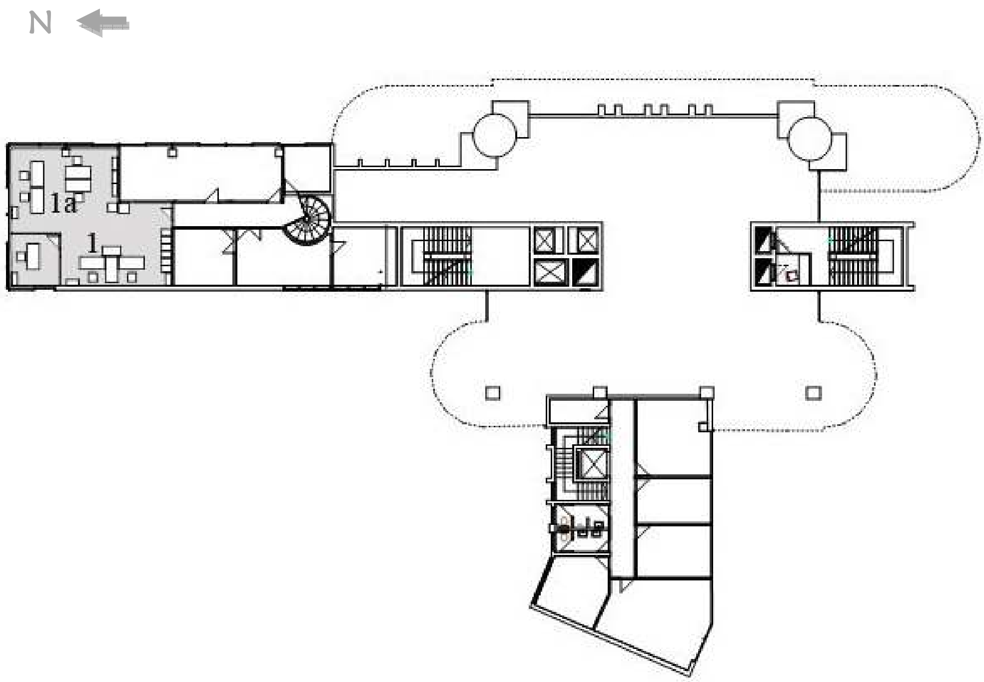

Fig. B 4: Schematic plan of office nr. 1 and 1a at the mezzanine (east, north and west oriented)

9.3 Appendix C: Questionnaire

The set of questions used during the interview phase is presented in Table C1.

Table C 1: Structure of the questionnaire

1. General Information	
1. Personal information	
1.1 Gender	m, f
1.2 Age from	1 (under 25) to 5 (above 55)
1.3 Occupation	Text
1.4 How many hours in average do you work per week?	[h]
1.5 Of these, how many hours do you spend at your workstation?	[h]
1.6 What percentage of your work do you perform on your computer?	[%]
1.7 How long have you been working in your current office?	Months
2. Evaluation of the indoor climate and environ control systems.	
2.1 How do you find the air quality of your office?	from +2 (Very good) to -2 (Very bad)
2.2 Are you satisfied with the possibility to ventilate your office?	from +2 (Very satisfied) to -2(Not at all)
2.2a If not, please give reasons why! Text	Text
2.3 How is the average temperature in your office in winter?	from -2 (Cold) to +2 (Hot)
2.4 How is the average temperature in your office in summer?	from -2 (Cold) to +2 (Hot)
2.5 How satisfied are you with the heating system in your office? from +2 (Very satisfied) to -2 (Not at all)	from +2 (Very satisfied) to -2 (Not at all)

2.6 How satisfied are you with the Air-conditioning? from +2 (Very satisfied) to -2 (Not at all)	from +2 (Very satisfied) to -2 (Not at all)
2.7 Do you have sufficient daylight in your office?	from +2 (Too much) to -2 (Not sufficient)
2.8 Are you annoyed by direct sunlight at your workstation?	from -2 (Frequently) to +1 (Never)
2.9 Are you annoyed by reflections or too bright surfaces on your computer screen?	from -2 (Frequently) to +1 (Never)
2.10 Do you have sufficient artificial light in your office? from +2 (Too much) to -2 (Not sufficient)	from +2 (Too much) to -2 (Not sufficient)
2.11 Are you annoyed by noise in your office?	from -2 (Frequently) to +1 (Never)
2.11a In case you marked „yes", "frequently" or "occasionally", please specify the source of noise!	Text
2.12 Evaluate the distance of your workstation from the window.	from +1 (Too close) to -1 (Too far)
2.14 Do you have enough privacy in your office to work undisturbed?	from +1 (Yes) to -1 (No)
2.14a In case you marked „no", please explain why!	
3. Operation and accessibility of the systems and system controls	
3.1 Can you open the windows of your office if required?	from -2 (Impossible) to +2 (Very easy)
3.2 How important is it for you to have the possibility to open the windows?	from -2 (Unimportant) to +2 (Very important)
3.3 Can you decide independently when to open/close the windows in your office or do you have to negotiate with other people?	Yes/No

In case you marked „with others“, please describe the process – who, when and how?	Text
3.6 Can you decide independently when to operate the internal shades in your office or do you have to negotiate with other people?	Yes/No
In case you marked „with others“, please describe the process – who, when and how	Text
3.7 Is the light switch easily accessible to you?	from -2 (Impossible) to +2 (Very easy)
3.8 Can you decide independently when to switch on/off the light in your office or do you have to negotiate with other people?	Yes/No
In case you marked „with others“, please describe the process – who, when and how.	Text
3.9 Is the thermostat easily accessible to you?	from -2 (Impossible) to +2 (Very easy)
3.10 Can you regulate the temperature on your own or do you have to negotiate with other people?	Yes/No
In case you marked „with others“, please describe the process – who, when and how	Text

4. Awareness of the functionality of the building control systems and energy conscious behaviour	
4.1 Are you sufficiently informed about how the following systems (heating, ventilation, air-conditioning, lighting) work in your office?	from -1 (Not sufficient) to +1 (Very good)
4.2 Have you ever had a training concerning the systems in your office?	Yes/No
If „yes“, how do you evaluate this training?	Text
If „no“, would you be interested in such training?	from -1 (No) to +1 (Yes)
4.3 To whom do you refer in case of a problem with the building systems (heating, lighting, etc.)?	Text
4.4 Are you satisfied with the system services and support in your office?	from -1 (No) to +1 (Yes)
4.5 Do you think that you can influence building energy consumption in the way you operate building systems?	from -1 (No) to +1 (Yes)
4.6 Do you think about energy conservation, when you operate building systems?	from -1 (No) to +1 (Yes)

9.4 Appendix D: Psychometric charts

Measured indoor temperature and relative humidity values plotted on psychrometric charts are illustrated in this section.

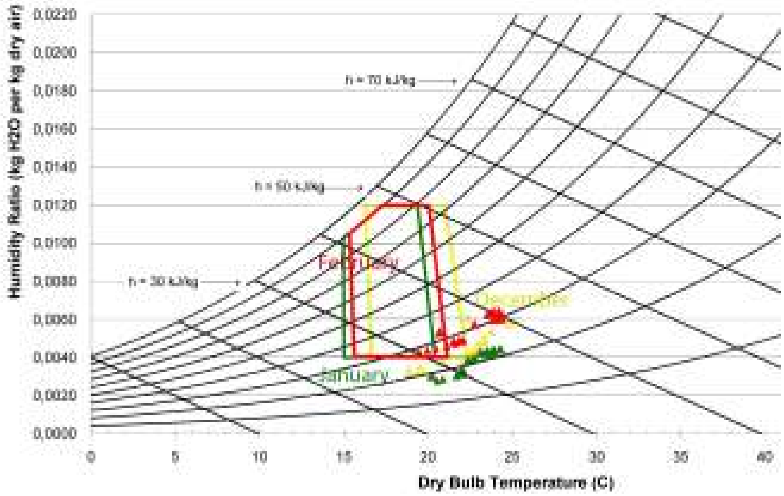

Fig. D 1: Hourly indoor temperature and relative humidity values at office nr.1 (mezzanine floor) during the months: December, January, February (8:00 – 17:00)

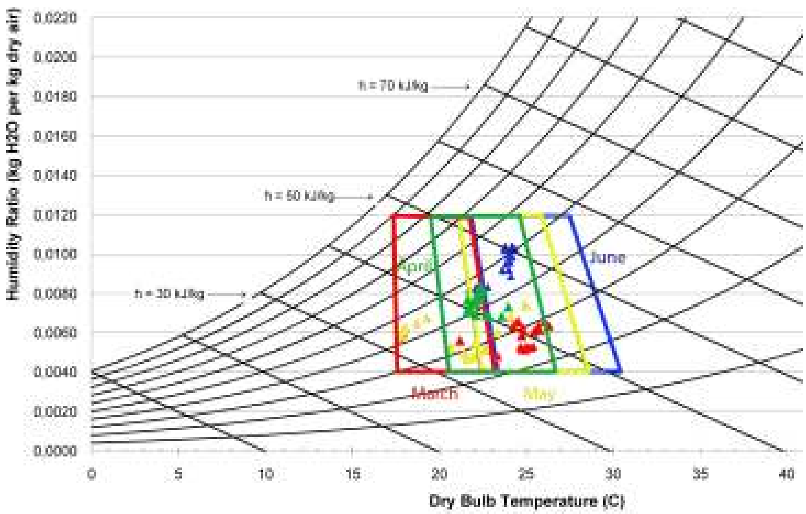

Fig. D 2: Hourly indoor temperature and relative humidity values at office nr.1 (mezzanine floor) during the months: March, April, May, June (8:00 – 17:00)

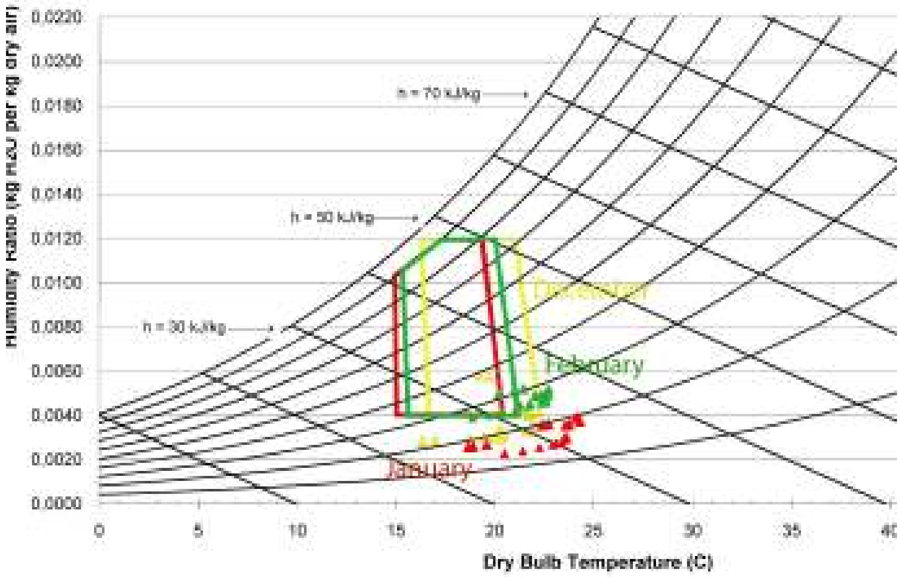

Fig. D 3: Hourly indoor temperature and relative humidity values at office nr.5 on the first floor during the months: December, January, February (8:00 – 17:00)

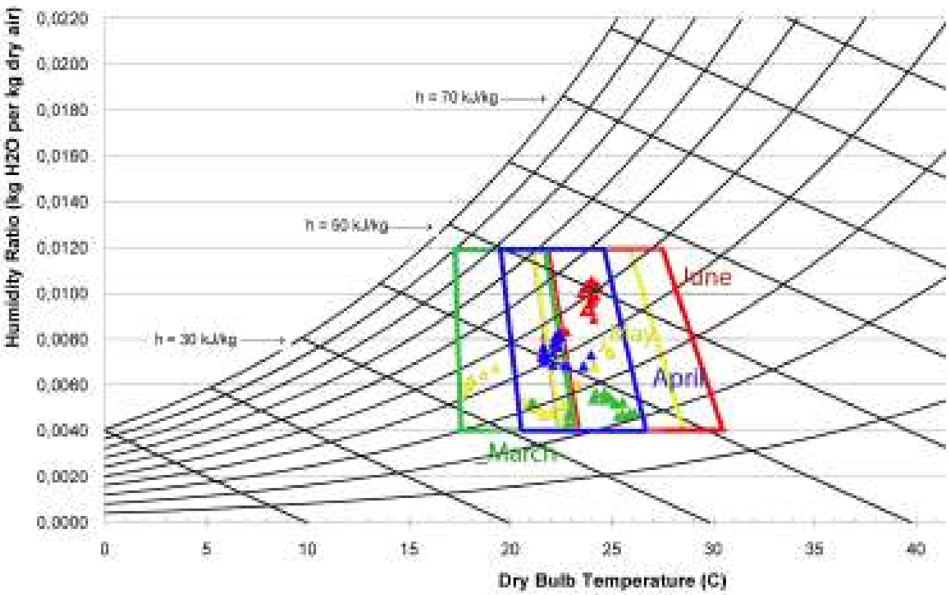

Fig. D 4: Hourly indoor temperature and relative humidity values at office nr.5 on the first floor during the months: March, April, May, June (8:00 – 17:00)

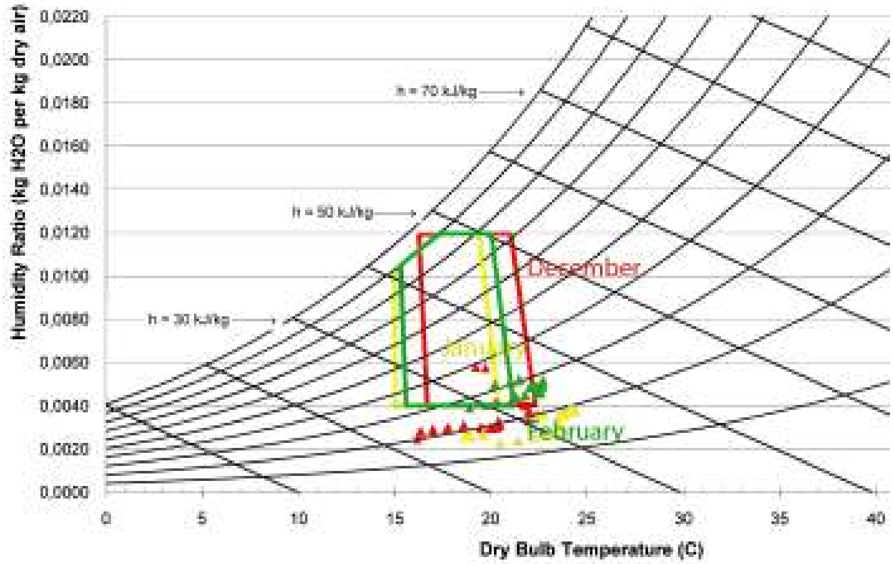

Fig. D 5: Hourly indoor temperature and relative humidity values at office nr.3 on the second floor during the months: December, January, February

(8:00 – 17:00)

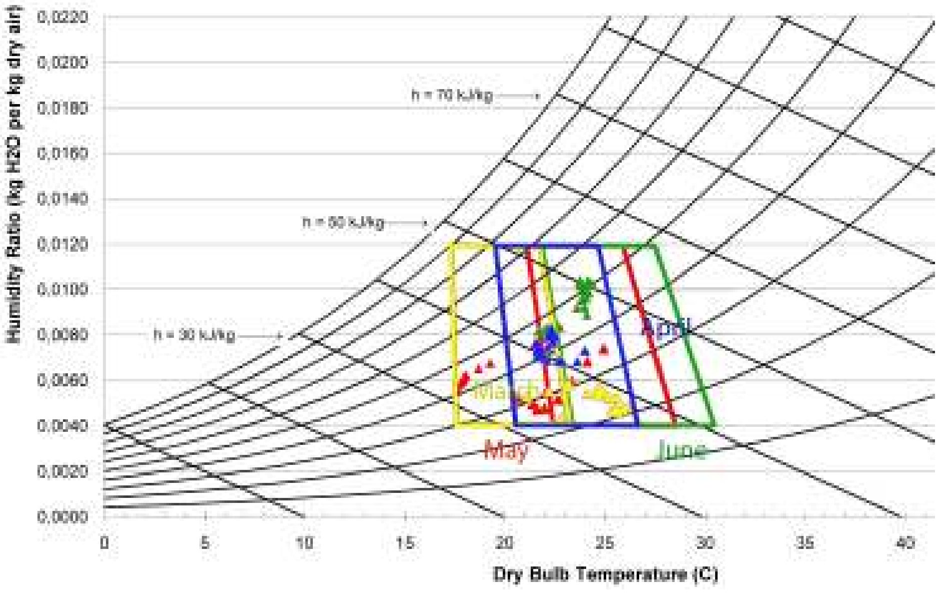

Fig. D 6: Hourly indoor temperature and relative humidity values at office nr.3 on the second floor during the months: March, April, May, June

(8:00 – 17:00)

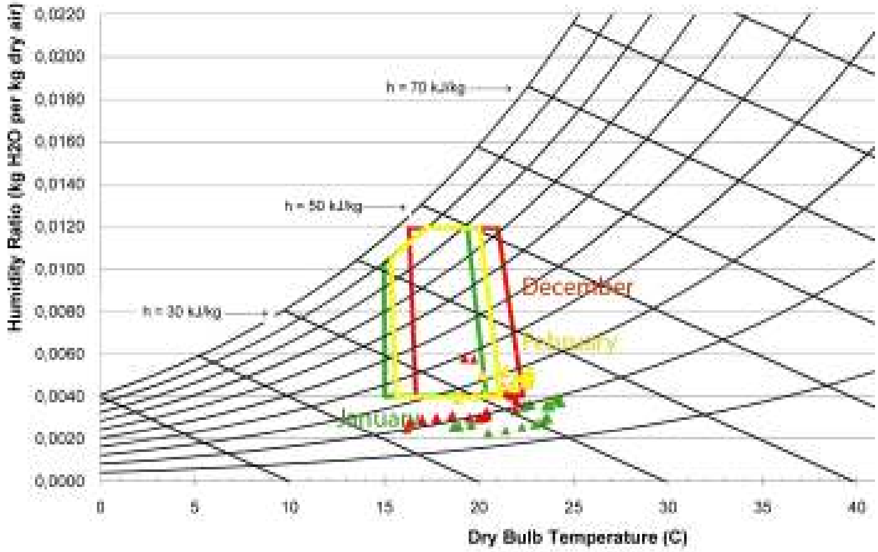

Fig. D 7: Hourly indoor temperature and relative humidity values at office nr.6 on the seventh floor during the months: December, January, February (8:00 – 17:00)

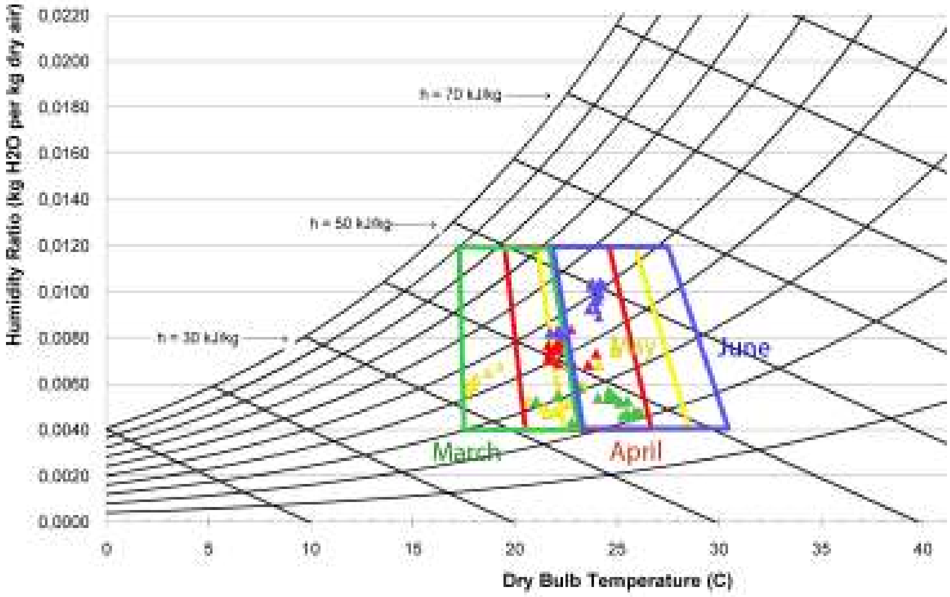

Fig. D 8: Hourly indoor temperature and relative humidity values at office nr.6 on the seventh floor during the months: March, April, May, June (8:00 – 17:00)

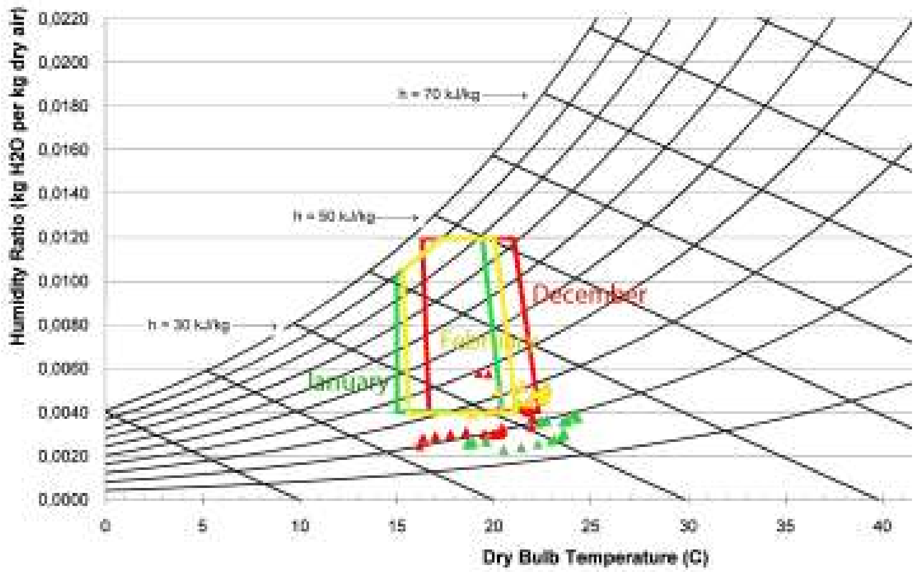

Fig. D 9: Hourly indoor temperature and relative humidity values at office nr.7on the eighth floor during the months: December, January, February (8:00 – 17:00)

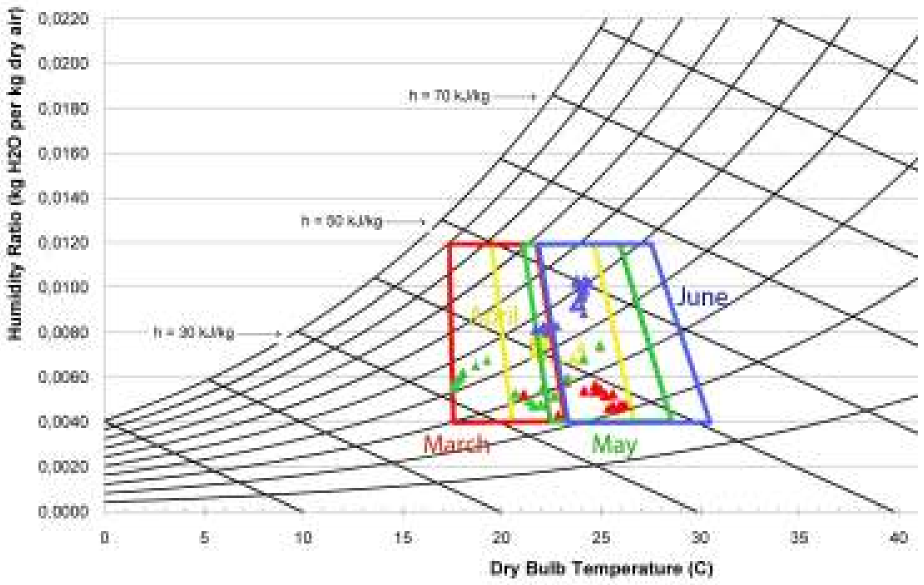

Fig. D 10: Hourly indoor temperature and relative humidity values at office nr.7 on the eighth floor during the months: March, April, May, June (8:00 – 17:00)

9.5 Appendix E: Predicted Mean Vote – PMV

Fig. E1 to E4 demonstrates results on calculated predicted mean vote and predicted percentage of dissatisfied.

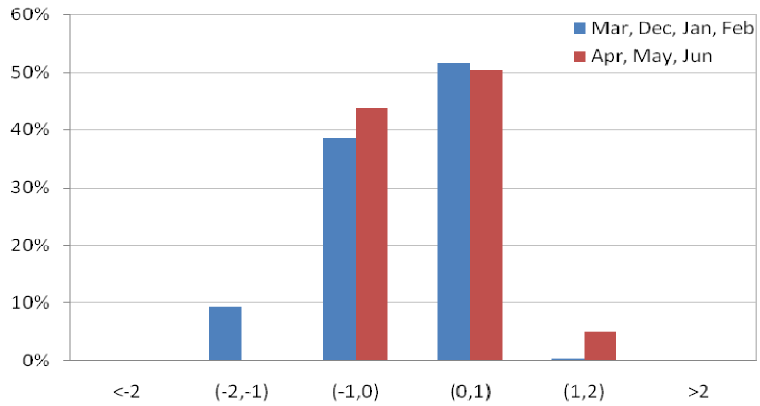

Fig. E 1: Distribution of calculated PMV at office nr. 1 during the months: December, January, February, March and April, May, June

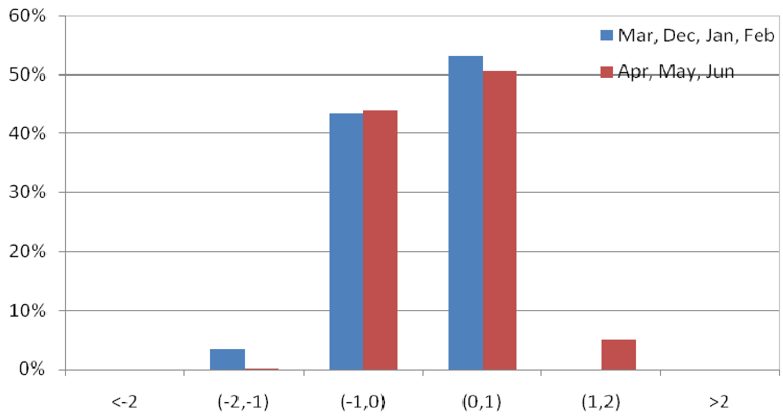

Fig. E 2: Distribution of calculated PMV at office nr. 1a during the months: December, January, February, March and April, May, June

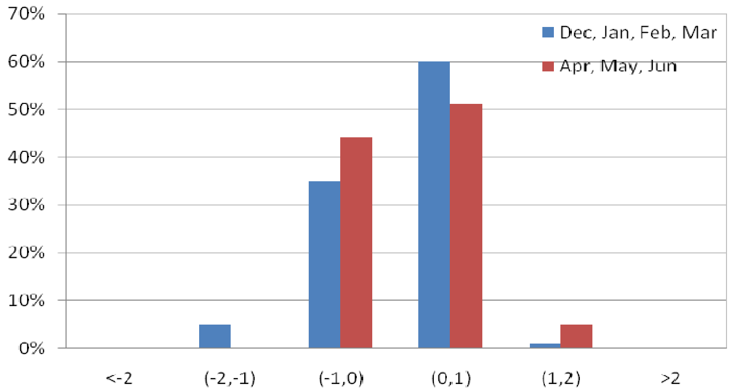

Fig. E 3: Distribution of calculated PMV at office nr. 3 during the months: December, January, February, March and April, May, June

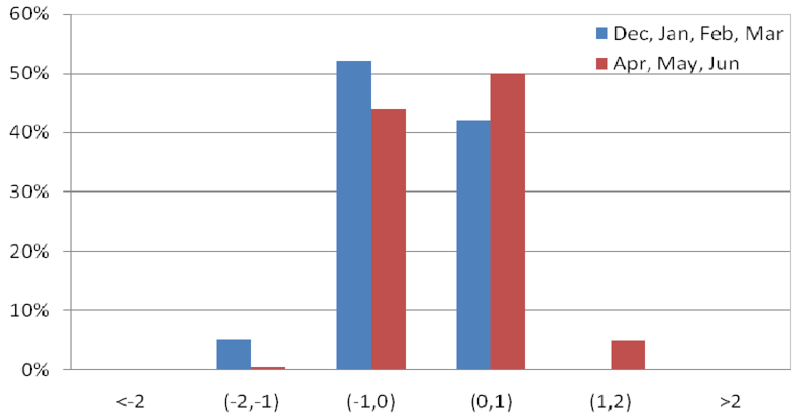

Fig. E 4: Distribution of calculated PMV at office nr. 4 during the months: December, January, February, March and April, May, June